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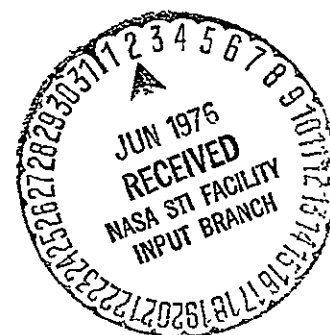
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TIMELINE ANALYSIS PROGRAM (TLA-1) FINAL REPORT

K. H. Miller

April 1976

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**Boeing Commercial Airplane Company
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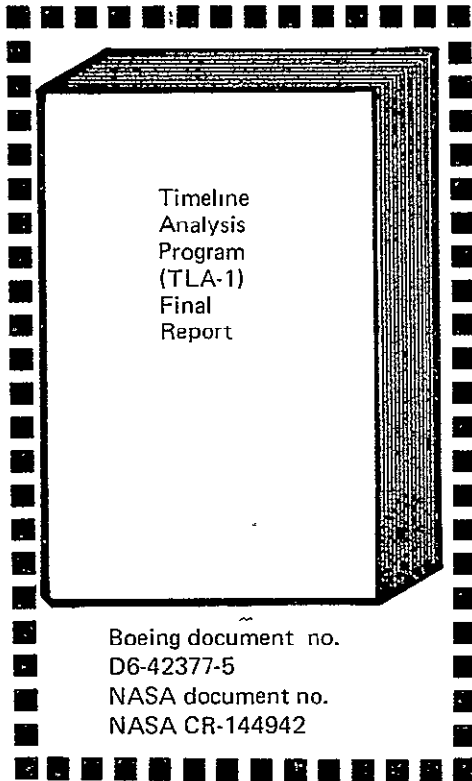
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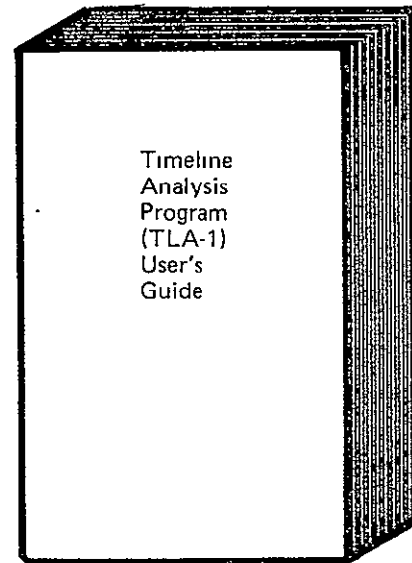
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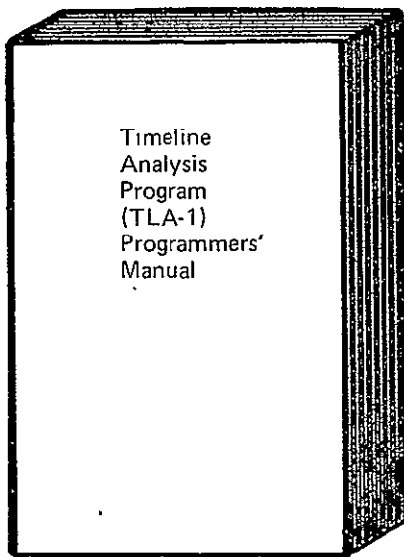


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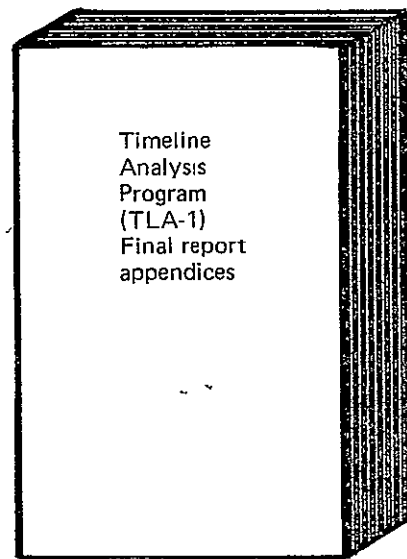
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16 Abstract This document is the final report for the Timeline Analysis Program (TLA-1) produced under NASA contract NAS1-13741. TLA-1 is a crew workload analysis computer program that was developed and expanded from previous Boeing workload analysis programs. TLA-1 was created for use on the NASA-Langley Terminal Controlled Vehicle Program. This document describes the derivation of input data for, the data processing of, and the output data from the TLA-1 model. Also described are eight scenarios that were created, programmed, and analyzed as verification of this model.					
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TIMELINE ANALYSIS PROGRAM (TLA-1)

FINAL REPORT

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1.0 SUMMARY

This document is the final report for the Timeline Analysis Program, NASA contract NAS1-13741. The report describes the derivation, details, and application of a crew workload analysis computer program, called TLA-1 (TimeLine Analysis program-Model 1), that was created for use on the Terminal Controlled Vehicle (TCV) program at NASA-Langley.

The application of TLA-1 requires an analyst to define (1) a scenario, (2) tasks, (3) events and procedures, (4) flight phases, and (5) subsystems. The analyst codes data relevant to these factors on preprinted data coding forms. These data are keypunched and then processed by using the TLA-1 program on the CDC 6600 computer to provide a variety of digital reports and graphical plots that provide a variety of statistical measures of crew workload.

Eight scenarios were developed, based on the NASA 515 aircraft operating in the Atlanta Airport terminal area. Procedures and tasks for both the forward flight deck and aft flight deck were detailed. Some of these data cases were processed by using TLA-1, and samples of every report and plot option were produced.

The software for the TLA-1 model and data cases was implemented on the NASA-Langley CDC 6600 computing system. NASA analysts and programmers were trained in the use of this software.

This final report, including the Appendices (Boeing document D6-42377-6), the TLA-1 User's Guide (Boeing document D6-42377-3), and the TLA-1 Programmer's Guide (Boeing document D6-42377-4), and the software and data package constitute the deliverable documentation for this program.

2.0 INTRODUCTION

2.1 THE NEED FOR TASK/WORKLOAD ANALYSIS ON THE TCV PROGRAM

NASA's Terminal Configured Vehicle (TCV) program is an advanced technology development activity focused on conventional transport aircraft that will routinely operate in reduced weather minima in future high-density terminal areas equipped with new landing systems, navigational aids, and increased ATC automation presently under development by the FAA and DOT.

The broad objectives of the program are to evaluate new concepts in the airborne systems (avionics and air vehicle) and operational flight procedures for (1) reducing approach and landing accidents, (2) reducing weather minima, (3) increasing air traffic controller productivity and airport and airway capacity, (4) saving fuel, (5) and reducing noise by more efficient terminal area techniques.

A Boeing 737-100 series airplane was obtained, and a second flight deck and an array of computers and monitors were installed in the passenger cabin (fig. 1). The airplane (NASA 515) was designated the research support flight system (RSFS). The RSFS is designed to be normally flown from the forward flight deck by using the primary flight control system, and from the aft deck by using a fly-by-wire, triple-redundant, digital flight control computer system. From the aft flight deck, the airplane can be flown under simulated Category III (CAT III) operations with safety assured through monitoring and takeover capability by the forward flight deck crew.

Since piloting tasks using advanced controls and displays in the future terminal area environment will differ from present concepts, it is imperative to ensure that these tasks will not become overly complex, demanding, or critical to safe operation. Task and workload analysis for the NASA 515 is therefore a necessity.

2.2 WORKLOAD ASSESSMENT METHODS

2.2.1 INTRODUCTION

Statements about "reducing operator workload" have frequently been included in lists of objectives for any crew systems design effort. If care is taken that the operator is not underloaded to the point of decreased motivation and vigilance, there should be no quarrel with the objective. However, even a cursory review of the literature shows an unusual diversity, and often vagueness, in the way the term "operator workload" is defined and used.

In determining how workload should be measured, one needs to keep in mind that it may not be possible to measure operator workload directly but that it should be possible to derive the needed measure by appropriate combinations of relevant quantitative empirical laws or functional relationships.

A comprehensive discussion of the scope of workload measurement theory and practice is found in ref. 1.

2.2.2 CONCEPTS OF WORKLOAD MEASUREMENT

Interest in accurate operator workload assessment and prediction develops because questions such as the following require meaningful answers during the design of equipment and the development of operating, training, and personnel selecting procedures:

- How easy is the equipment to operate?
- How much attention is required during equipment operation?

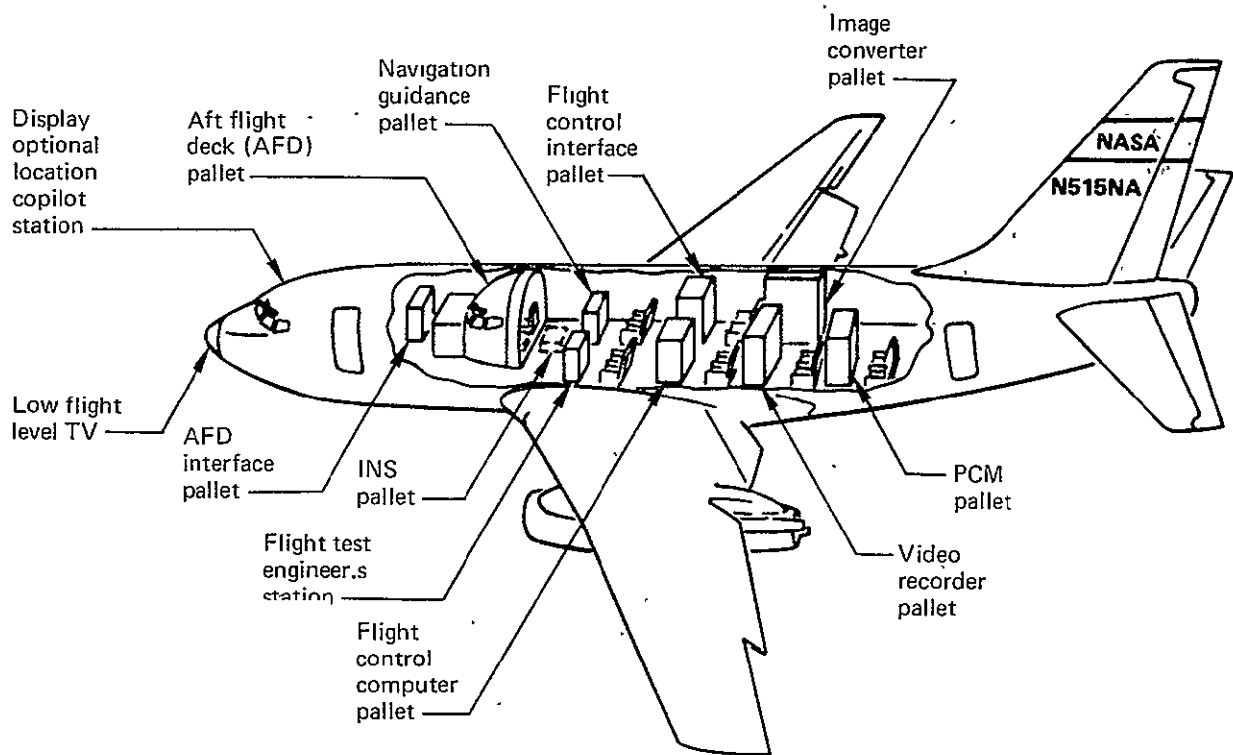


Figure 1. Research Support Flight System Internal Arrangements

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- How much learning is involved to master the equipment?
- How well will the operator be able to perform additional foreseen and unforeseen tasks?

All these questions are directed toward finding an indication of the extent to which an operator is occupied by a task.

Basically, four categories of workload measurement methods have been identified:

1. Information processing methods
2. Operator activation-level methods
3. Equipment design-implicit methods
4. Time-and-motion methods

The following sections briefly discuss each of these methods.

2.2.2.1 Information Processing Methods

The use of information processing methods to determine operator workload is based on the premise that the human operator possesses a fixed, limited channel capacity and that workload is either the degree to which tasks additional to a primary one can be accomplished or the degree to which auxiliary tasks interfere with the accomplishment of the primary task. The underlying concept here is similar to that of time-and-motion techniques, except that the emphasis is shifted toward a quantitative determination of "excess channel capacity" as a measure of operator workload.

2.2.2.2 Operator Activation-Level Methods

Briefly stated, the "activation" or "arousal" hypothesis maintains that the level of physiological activity within the central nervous system (CNS) is increased both by the mental demands made by the working situation and by the intensity of physical stimuli. In the area of workload assessment, it is hypothesized that input load is a determinant to the activation level that is reflected in the physiological activity of the individual. Thus, physiological measurement techniques are used to correlate changes in heart rate, sinus arrhythmia, EEG, cortical evoked potentials, integrated EMG, respiration rate, and pupillary dilation, as well as others, with various task conditions.

2.2.2.3 Equipment Design-Implicit Methods

Studies in this category maintain that changes in operator performance are directly associated with changes in workload. Thus, performance improvements that can be related to changes in equipment or procedures are also assumed to indicate a reduction in operator workload. Subjective rating of task difficulty is generally combined with operator performance measures to deduce that operator workload has changed.

Unfortunately, most studies of this type include only a brief statement that operator workload has been changed but do not state how workload was defined or how the conclusion was reached.

2.2.2.4 Time-and-Motion Methods

The time-and-motion approach to workload evaluation relies heavily on detailed task analyses that require some techniques derived from time-and-motion engineering. This approach is used primarily during system development and represents the broadest approach to workload assessment, since the primary concern is to determine the operability of a proposed system. The question becomes simply: Can the operator satisfactorily accomplish all the tasks allocated to him within the time frame available to meet mission phase and/or system requirements?

This is the workload measurement method that is employed in the Timeline Analysis program (TLA-1).

2.3 THE TIMELINE ANALYSIS (TLA-1) PROGRAM

The TLA-1 program was created to improve and expand the capabilities of an existing validated Boeing task/workload model¹ for use on the TCV program. TLA-1 will support NASA-TCV objectives by: (1) producing a detailed analytic model for performing task and workload analyses on alternative control-display concepts in the TCV and (2) developing a baseline set of data for comparing crew workload in the fore and aft cabs of the TCV in a commercial airline environment.

¹The workload model that is the basis for TLA-1 is called Workload Evaluation for Cockpit Crew (WECC). WECC was developed, applied, and validated as part of the Boeing 747 certification program. Data were accepted by FAA as part of the certification package.

3.0 SYMBOLS AND ABBREVIATIONS

ADF/RMI	automatic direction finder/radio magnetic indicator
AFD	aft flight deck
AGCS	advanced guidance and control system
APU	auxiliary power unit
ARTCC	air route traffic control center
ATA	Air Transport Association
ATC	air traffic control
ATT CWS	attitude control wheel steering
AUD	auditory
AVC	weighted average channel
AVE	average only
A+1	average plus 1σ
CAS	channel activity summary
CAT III	Category III
CI	course indicator
CNS	central nervous system
COG	cognition
COM	communication
CSD	constant speed drive
CWP	crewman workload profile
CWS	control wheel steering
CWS	crewman workload summary statistics
DME	distance measuring equipment

EADI	electronic attitude director indicator
EPR	engine pressure ratio
EV	external vision
FAA	Federal Aviation Administration
FDI	flight director indicator
FFD	forward flight deck
FL	flight level
IFR	instrument flight rules
ILS	instrument landing system
INS	inertial navigation system
IV	internal vision
KIAS	knots indicated airspeed
LF	left foot
LH	left hand
MFD	multifunction display
MLS	microwave landing system
MNS	mission scenario
MOT	motor
MTL	mission timeline
NAVAID	navigational aid
NCDU	navigation control and display unit
N_{COC}	number of channel overload contributors
N_i	number of time intervals
$N_{\Delta T}$	number of study-time intervals in which a work overload occurs

PCM	power control module
PTA	planned time of arrival
RF	right foot
RH	right hand
R_{INT}	ratio of total channel overload contributors to total interval time
R_{MSN}	ratio of total channel overload contributors to total mission time
RNAV	area navigation
R_{PHS}	ratio of total channel overload contributors to total phase time
RSFS	research support flight system
SAS	subsystem activity summary
Selcal	selective call unit
SID	standard instrument departure route
SR1, . . . , SR4	standard report request
SSA	subsystem activity
STAR	standard arrival route
S_W	workload sum
S_{W2}	sum of the squares of workload
T	slide time, turn time
TCA	task channel activity
TCV	terminal configured vehicle
TFR	terrain following radar
t_{IE}	interval end time
T_{INT}	total interval time
t_{IS}	interval start time

T_{ISF}	first interval in which task contributes to workload
T_{ISL}	last interval in which task contributes to workload
TLA-1	Timeline Analysis Program, Model 1
TLS	task list
TST	test
t_T	task duration time
t_{TE}	task end time
t_{TS}	task start time
VBL	verbal
VIS	visual
VOR/RMI	very high frequency (VHF) omnidirectional radio/radio magnetic indicator
\bar{W}	mean workload
W_A	channel workload for a study-time interval
W_C	channel workload
W_{CT}	percent channel workload
$W_{CT,N}$	allocated channel N activity
WECC	workload evaluation for cockpit crew
W_G	channel group workload
WLH	workload histogram
WLS	workload summary
W_{OVLD}	total channel overload contribution
2D	horizontal path mode
3D	vertical path mode
4D	time path mode

Δt	study interval
ΔT_{INT}	total interval time
ΔT_{MSN}	total mission time
ΔT_{PHS}	total phase time
Δt_T	task duration time
σ	standard deviation of the workload
σ^2	workload variance

4.0 TLA-1 PROGRAM OVERVIEW

Figure 2 shows the overall TLA-1 analytical and data processing procedure. Each element in figure 2 will be briefly discussed in this section. Detailed descriptions of the derivation and use of the various items are given in other sections of this report. The TLA-1 User's Guide (ref. 2) and Programmer's Guide (ref. 3) provide additional detailed information.

Application of TLA-1 includes three major phases:

1. Input data preparation (sec. 4.1)
2. Data processing (sec. 4.2)
3. Output data analysis (sec. 4.3)

4.1 INPUT DATA PREPARATION

Four activities are involved in the preparation of the TLA-1 input data:

1. Scenario development
2. Task data derivation
3. Task timeline development
4. Input data coding

Scenario development and task data derivation are performed first and can be done independently. Task timeline development and input data coding are performed after the first two activities are completed.

4.1.1 SCENARIO DEVELOPMENT

Crew workload is a measure of how well the crew can accomplish a given set of tasks within the available time. The set of tasks to be performed and the time available for performance are dictated by the scenario.

A scenario is a time-based sequence of events that defines the significant milestones that occur during the mission being studied. The following events are defined in a flight mission scenario:

- Begin taxi
- Taxi maneuvers on ramps

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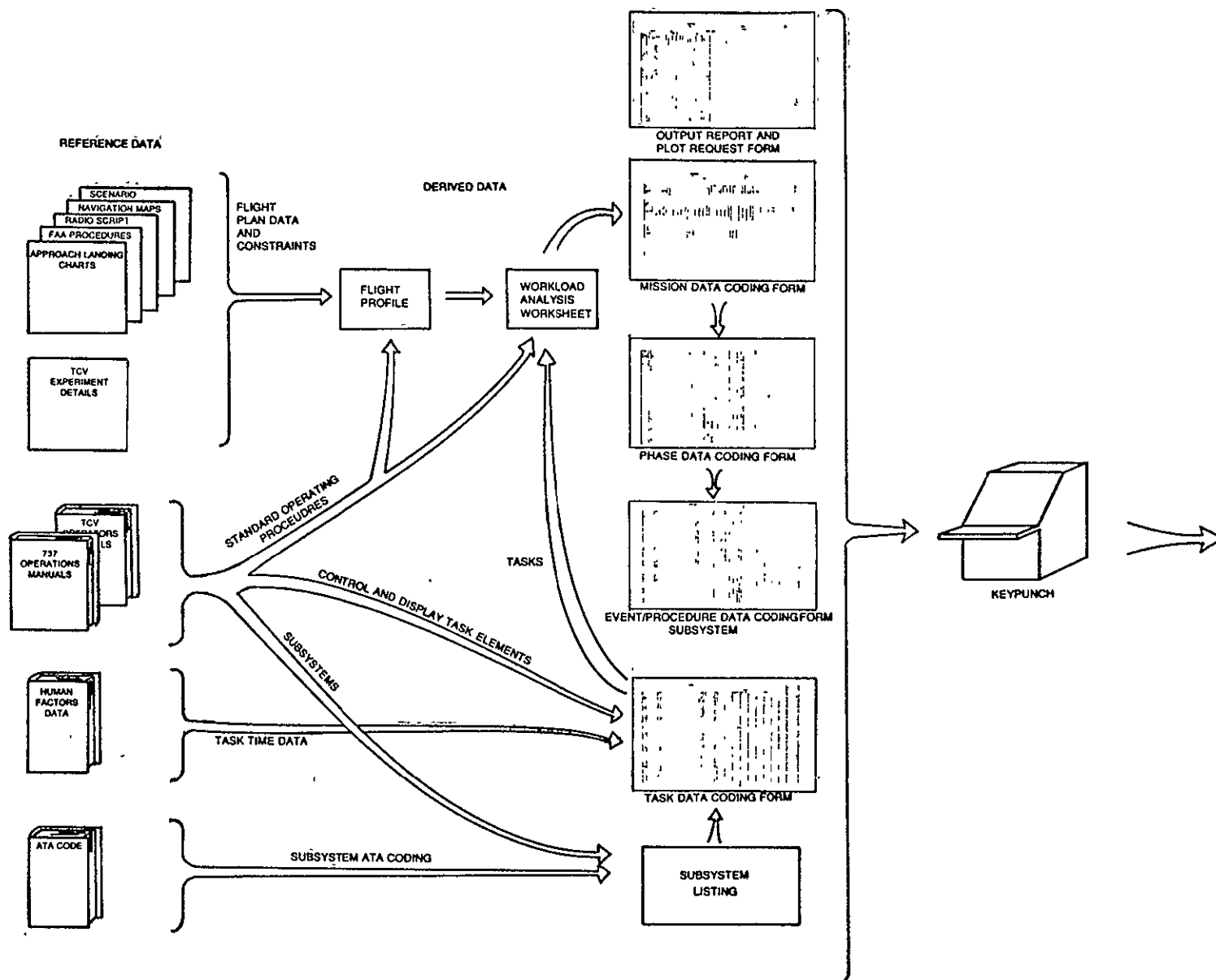


Figure 2.—TLA-1 Analytical Process

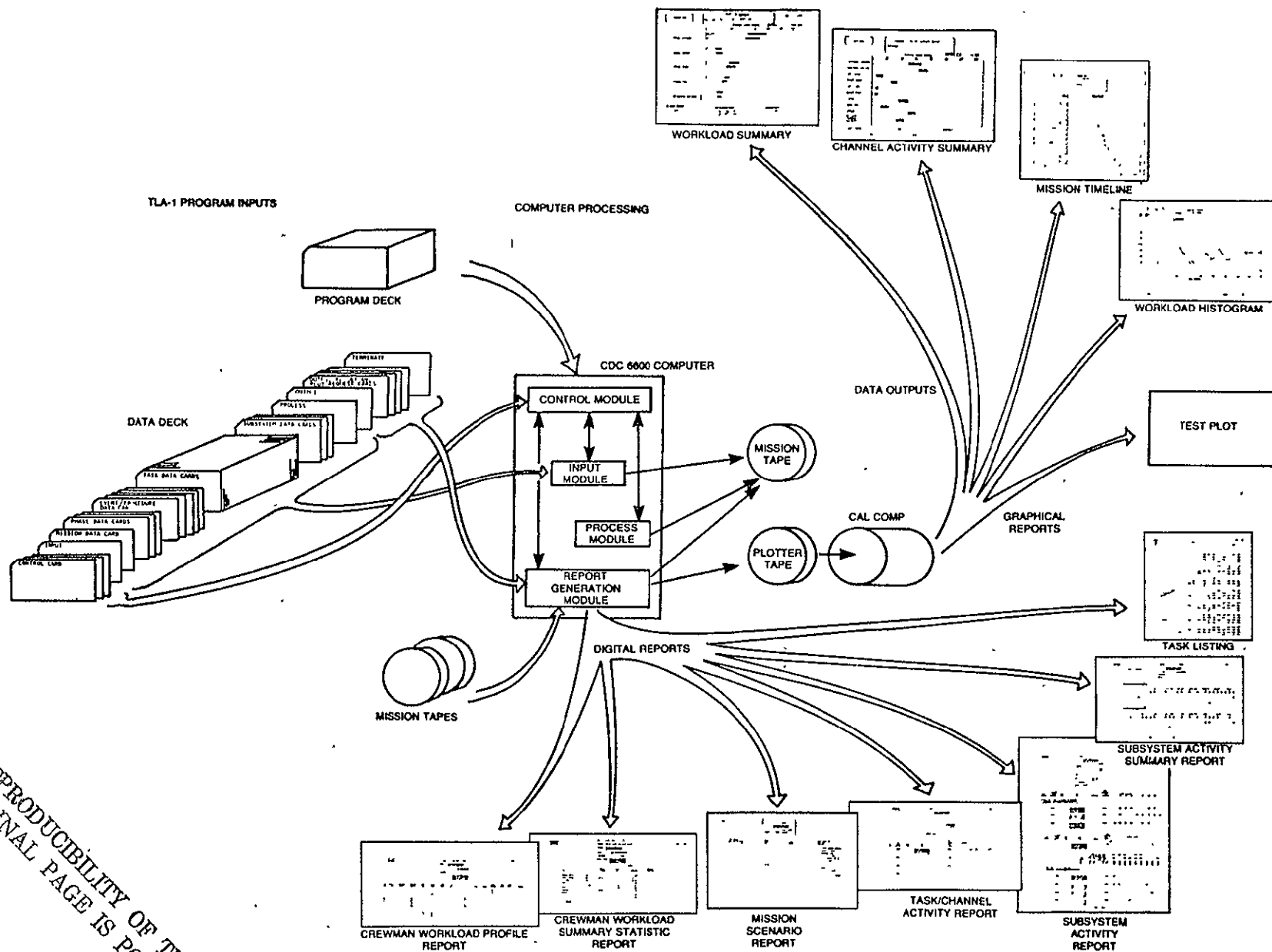


Figure 2.—Concluded

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- Brake release
- Takeoff
- Gear up
- Flap retractions—each step in retraction sequence
- Horizontal maneuvers—start/end times of each maneuver
- Vertical maneuvers—start/end times of each maneuver
- Speed changes—start/end times of each transition
- Navaid crossover/handover
- Flap extensions—each step in extension sequence
- ILS or MLS localizer and glideslope intercept points
- Gear down
- Touchdown
- Taxi maneuvers on ramps
- Park
- Shutdown
- Radio messages incoming/outgoing—complete text of each message, frequencies used, etc.
- Malfunctions

The analyst must define the initiation time of each event.

Creation of the scenarios is based on the data derived from mission flight plans, TCV experiment test plans, flight information maps, approach and landing charts, ATC operation data, aircraft performance data, and aircraft operation manuals. The scenarios that were developed to verify the TLA-1 software are described in detail in section 5.0.

4.1.2 TASK DATA DERIVATION

In TLA-1, tasks are used as the basic work units from which all crew workload statistics are derived. Tasks are identified and cataloged for every control and display, every verbal communication, and every other crew action. A task catalog containing over 2000 tasks was derived (App. Five, ref. 4).

The tasks are categorized by subsystems. Each task description contains a task code number, a task description/name, task duration time, and the channel activity (left hand, right hand, left foot, right foot, external vision, internal vision, cognition, auditory, and verbal). These factors are discussed in detail in section 6.0.

The data from which the tasks are derived include:

1. Aircraft operation manuals
 - a. Checklists
 - b. Procedures
2. Human factors data
 - a. Eye fixation times
 - b. Reach times
 - c. Control activation times
 - d. Display monitoring times
3. Task simulation
 - a. Verbal communication delivery times
 - b. Task execution times

4.1.3 TASK TIMELINE DEVELOPMENT

After the scenarios and tasks have been defined, the analyst develops the detailed task sequences (procedures) required to execute the scenario.

A workload analysis worksheet (fig. 3) has been prepared for the analyst to use for detailing the procedures. In the process of filling in the details on this format, the analyst specifies all the data that will be entered in the various input data coding forms (discussed in sec. 4.1.4).

The analyst will use the following as reference data for the procedure detailing:

1. Aircraft operation manuals
 - a. Normal procedures
 - b. Abnormal procedures
 - c. Checklists
2. The scenario
3. The task catalog

The detailing is organized by defining flight phases (sec. 7.2) and events and procedures (sec. 7.3). The analytical process of detailing the scenarios on the worksheet requires careful attention to detail. This is the only place that all tasks, events, procedures, phases, timing relationships, and crew interactions are totally visible in an integrated format.

TLA-1 WORKLOAD ANALYSIS WORKSHEET

PAGE ____ OF ____

MISSION TITLE				CONFIGURATION				RUN DATE										
PHASE/EVENT/PROCEDURE DATA				TASK DATA														
CODE NO.	NAME/DESCRIPTION	START TIME			TASK CODE NO.	TASK NAME/DESCRIPTION	S	TASK DURATION (SECONDS)	MISSION TIME			TASK START TIME			SLIP (SEC)			P
		HR	MIN	SEC					HR	MIN	SEC	HR	MIN	SEC	-	+		
090006	RETRACT FLAPS TO FLAPS 1			33						37	15							
090007	REACH 3000 FT ABOVE RWY		1	11						37	53							
090011	RETRACT FLAPS TO FLAPS 0		1	31						38	13							
090056	ENGAGE VERT PATH GUIDANCE MODE		1	31	2H 07	AUTO SW	1	1.42		38	13		0	2	2	P		
					2H 08	AUTO HS	1	1.34					1.42					
					2H 35	HOZ PATH SW	1	1.37					2.76					
					2H 36	HOZ PATH ITS	1	.78					4.13					
					2H 39	VERT PATH SW	1	1.36					4.91					
					2H 40	VERT PATH ITS	1	.78					6.27					
					2K 14	MON MFD	2	10					7.05					
090057	CROSS WPT0Z (SIDZ) AUTOPILOT MANEUVERS A/c TO 088 HDG		1	36	2K 14	MON MFD	2	10		38	18		0			P		
					2K 33	MON CURVED TREND VECTOR	1	10					0					
					2K 47	MON TRACK ANGLE	1	10					0					
					2K 52	MON FLT PATH	1	10					0					
090067	MONITOR AUTO HEADING CHANGE		1	36						38	18							
030007	MON ENGINE INSTRUMENTS		1	40						38	22							
090012	TURN COMPLETED ON HDG 088		1	42						38	24							
090013	REACH 250 KNOTS		2	00						38	42							
090051	INST SCAN - A1		2	00						38	42							
030007	MON ENG INST		2	40						39	22							
090076	SET MFD MAP SCALE TO 32 NMI		1	48	2K 10	SEL 32 NMI	1	2.68		38	30		0			P		
					2K 17	MON MFD	1	2.37					2.68					

Figure 3.—Workload Analysis Worksheet

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4.1.4 INPUT DATA CODING

The analyst uses six sets of input data, with the following fixed-format coding forms:

1. Subsystem coding form
2. Task data coding form
3. Event/procedure data coding form
4. Phase data coding form
5. Mission data coding form
6. Report request coding form

These forms are briefly discussed in the following sections, and complete details are found in other sections of this report.

4.1.4.1 Subsystem Coding Form

The subsystem coding form (fig. 4) is used to define aircraft subsystems.

4.1.4.2 Task Data Coding Form

Task data coding forms (fig. 5) are filled out during the task data derivation stage. (See secs. 4.1.2 and 6.0.) The task is totally defined on this form by a unique task code number, a task description, a situation number, the task duration time, and the channel activity allocation.

4.1.4.3 Event/Procedure Data Coding Form

Event/procedure data coding forms (fig. 6) are filled out after the workload analysis worksheets are completed. (See secs. 4.1.3 and 7.0.) All the data to be entered on these coding forms come directly from the worksheets.

Events (see sec. 7.3.1) are defined by a unique code number and a description and are generally used to enter comments or milestones into output reports and plots. Events are distinguished from procedures because events have no tasks associated with them.

Procedures (see sec. 7.3.2) are defined by a unique code number, a title, and a listing of the sequence of tasks that are used in the procedure. Each task in the sequence is defined by the task code number, the initiation time of the task, the allowable initiation time limits, the crewmember who performs the task, and the task situation number.

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TLA-1
SUBSYSTEM CODING FORM

PROGRAM	PAGE	OF
FORM NUMBER	DATE	

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
SUBSYSTEM NAME										ATA CODE NO.																																																																																									

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Figure 4.—Subsystem Coding Form

PROGRAM	PAGE	of
PROGRAMMER	DATE	

[illegible]

Figure 5.—Task Data Coding Form

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Figure 6.—Event/Procedure Data Coding Form

4.1.4.4 Phase Data Coding Form

The various flight phases (takeoff, cruise, etc.) are defined by a phase code number, a descriptive name, and a listing of the sequence of events/procedures with their respective start times. (See sec. 7.2.) The data to be filled in one these forms (fig. 7) come directly from the workload analysis worksheets.

4.1.4.5 Mission Data Coding Form

The mission data coding form (fig. 8) is used to define the computational parameters; mission title, configuration, crewmembers, and sequence of flight phases and their respective start times. The flight phase data are taken from the workload analysis worksheets. The rest of the data is created by the analyst. (Refer to sec. 7.2.)

4.1.4.6 Report Request Coding Form

One of the most powerful features of TLA-1 is the wide variety of workload analysis data formats that are available. Six digital reports and four data plots can be requested. By specifying different variables for each of these output formats, literally thousands of data records can be selected for output for a mission. Obviously, not every conceivable report and plot will be requested at any one time. The report request coding form (fig. 9) is used to list the types of outputs and the variables. The various reports and plots are discussed in detail in section 8.2.1.3.

Definition has been made of standard sets of reports and plots that can be specified by number. The items in these standard report sets have been selected to provide a general visibility of the workload situation for a scenario. As high workload problems are isolated, the analyst can be more selective of the output types and exercise tighter control over the variables so that successive data outputs can expose the nature of the workload problems in more detail.

4.2 DATA PROCESSING

The program is divided into the following four modules (fig. 10):

1. *Control*—The control module processes all control cards and initiates the other three modules.
2. *Input*—All mission data are input through the input module and output to an external permanent file.
3. *Processor*—The processor module performs all the calculation functions and outputs the results to an external file. The input to the processor comes from the data stored by the input module.
4. *Report generation*—The report generation module receives inputs of report requests and acts to produce the requested reports by using the data from the two external files created by the input module and the processor module. As many as three sets

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TLA-1

PHASE DATA CODING FORM

PROGRAM	PAGE	OF
PROGRAMMER	DATE	

Figure 7.—Phase Data Coding Form

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MISSION DATA CODING FORM

PROGRAM	PAGE OF
PROGRAMMER	DATE

MISSION PARAMETERS										TIME INTVL (SEC)		STRT TM		SLIDE INTVL (SEC)		SLIDE THSHD %		RUN CODE		CONFIGURATION															
RUN DATE										MISSION TITLE																TITLE									
MISSION PROFILE																																			
NO.																																			
PHASE CODE NO.		START TIME			PHASE CODE NO.		START TIME			PHASE CODE NO.		START TIME			PHASE CODE NO.		START TIME			PHASE CODE NO.		START TIME			PHASE CODE NO.		START TIME								
HR MIN SEC		HR MIN SEC			HR MIN SEC		HR MIN SEC			HR MIN SEC		HR MIN SEC			HR MIN SEC		HR MIN SEC			HR MIN SEC		HR MIN SEC			HR MIN SEC		HR MIN SEC								
CREWMEMBERS																																			
NO.																																			
NAME							NAME							NAME																					

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Figure 8.—Mission Data Coding Form

Figure 9.—Report Request Coding Form

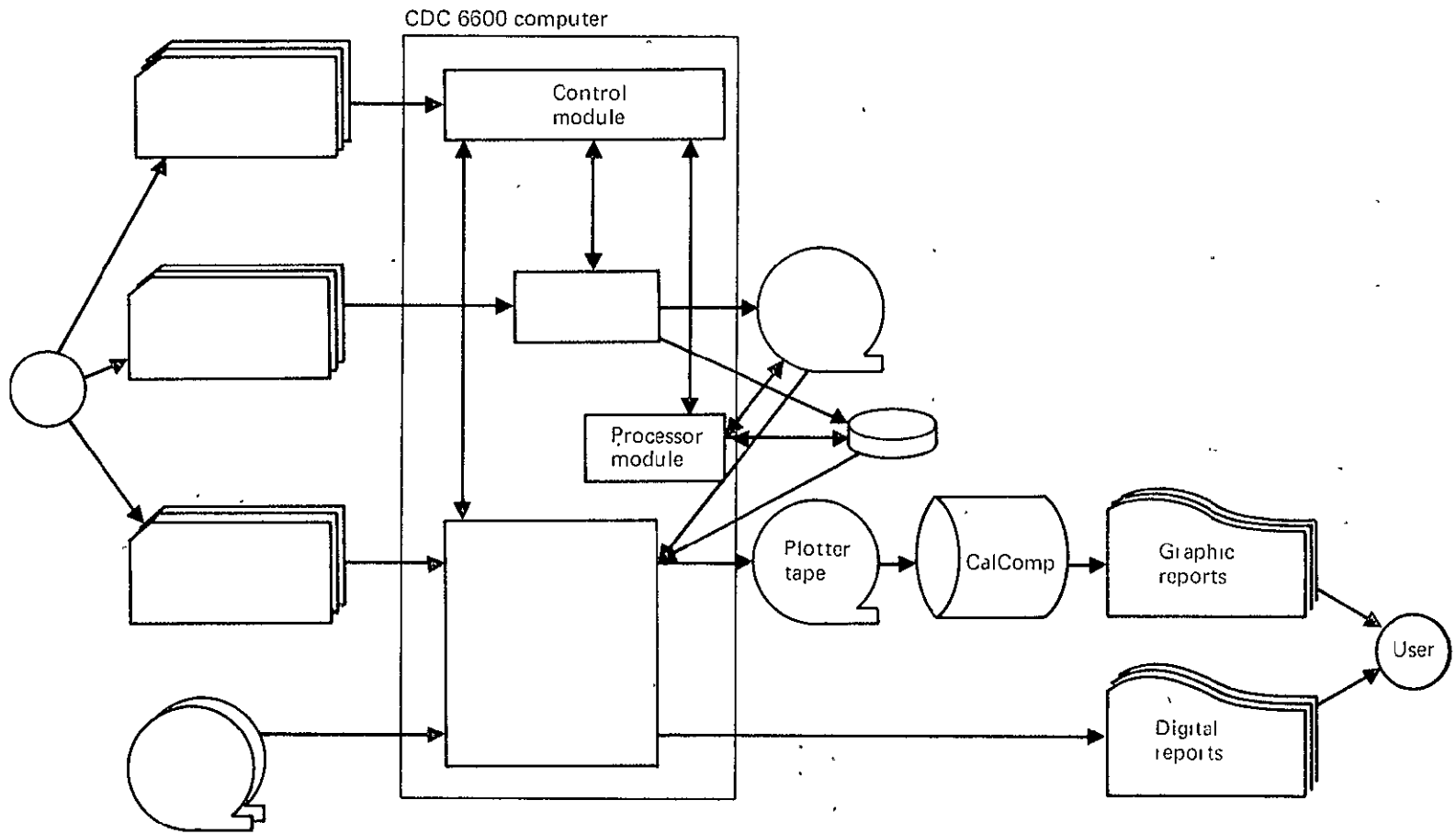


Figure 10.—TLA-1 System Diagram

of external files (different configurations of the same mission) may be input to create some reports.

This section will briefly discuss these modules. Complete details are in section 8.0 and in the TLA-1 User's Guide (ref. 2) and the TLA-1 Programmer's Guide (ref. 3).

4.2.1 INPUTS

Inputs to TLA-1 are from two sources: card and tape. The following sections describe the card types and formats and the tape inputs.

4.2.1.1 Card Inputs

Card inputs to TLA-1 are of three classes: control specifications, mission data, and report request specification.

The control specifications cause the functions to be executed. The mission data prescribe in detail a mission timeline task. The report request specification causes reports to be generated.

4.2.1.1.1 Control Card.—Control card input is used to initiate four functions: (1) input, (2) process, (3) output, and (4) terminate.

The input control card function causes the mission specification data to be input from cards, listed, and output to the mission tape.

The process control card function causes the mission data from the mission tape to be read, performs all functions specified in section 4.2.2, and outputs the processing results to a second file on the mission tape.

The output control card function causes the report request specification cards and one, two, or three mission tapes to be read and causes the requested reports and plot tapes to be created.

The terminate control card function causes all files to be closed and causes termination of program execution.

4.2.1.1.2 Mission Data Input.—The mission data input is classified into the following five types discussed in sections 4.1 and 8.2:

1. Mission specification (See sec. 8.2.1.2.1.)
2. Phase specification (See sec. 8.2.1.2.2.)
3. Event/procedure specification (See sec. 8.2.1.2.3.)
4. Task specification (See sec. 8.2.1.2.4.)
5. Subsystem specification (See sec. 8.2.1.2.5.)

4.2.1.1.3 Report Request Specification.—There are 15 different inputs that are used to specify the reports to be generated. They are divided into three types:

1. Digital report request (See secs. 4.3.2 and 8.2.1.3.1.)
2. Graphic report request (See secs. 4.3.3 and 8.2.1.3.2.)
3. Class output request (See sec. 8.2.1.3.3.)

4.2.1.2 Mission Tape Input

This tape consists of two files: one contains the mission data card input and the other contains the processor module output. This tape is read by the output module to derive the data to be used on the reports and plots.

4.2.2 PROCESSING FUNCTIONS

This section describes the following functions to be performed to produce data for the output reports: (1) task processing, (2) phase statistics, (3) task-situation time shift, (4) task-channel activity calculations, and (5) subsystem activity calculations. Complete details are in section 8.3.

4.2.2.1 Task Processing

The task processing function uses the task-situation channel workloads and performs the following:

1. Calculates the time intervals spanned by the task situation
2. Calculates the workload contributions to study-time intervals
3. Updates the study-time interval workload sums
4. Calculates the channel group workload
5. Calculates the weighted average channel workload

4.2.2.2 Phase Statistics

The following statistics are calculated across all time intervals in a phase for each channel, each channel group, and the weighted average channel:

1. Workload sum S_W
2. Sum of the squares of workload S_{W^2}
3. Mean workload \bar{W}

4. Workload variance σ^2
5. Standard deviation of the workload σ

4.2.2.3 Task-Situation Time Shift Function

After all task processing has been completed, the shift function will be performed if the option is specified. The shift function checks each time interval in turn to determine if any channel workload exceeds a specified shift threshold criterion. If a channel workload exceeds the shift threshold, an attempt is made to slide start times of those task situations contributing to the workload excess. Only those task situations that have the slide option specified are used to attempt reduction of the excess workload.

4.2.2.4 Task-Channel Activity Calculations

This set of calculations gives the percent of interval time that a task-situation channel workload contributes to an interval total channel workload if the interval total channel workload exceeds a report threshold.

4.2.2.5 Subsystem Activity Calculations

The purpose of the subsystem activity calculations is to measure how much of the time the subsystem is involved in workloads exceeding given thresholds.

4.3 OUTPUT DATA

Program outputs are to tape, printer, and plotter.

4.3.1 MISSION DATA TAPE

A tape consisting of two files will be used to store the mission data input and the processed data for later use by the report generation function. The first file will contain the mission data input, and the second will contain the processor output used by the report generation function.

4.3.2 DIGITAL PRINTER OUTPUT

The output to the printer consists of seven reports:

1. Mission scenario (sec. 8.4.2.1)
2. Crewman workload profile (sec. 8.4.2.2)
3. Crewman workload summary statistics (sec. 8.4.2.3)
4. Task-channel activity (sec. 8.4.2.4)
5. Subsystem activity (sec. 8.4.2.5)

6. Subsystem activity summary (sec. 8.4.2.6)
7. Task list (sec. 8.4.2.7)

The following sections describe these reports, which are generated as a result of report requests.

4.3.2.1 Mission Scenario Report

The mission scenario report outputs a timeline of the workload for specified mission phases. For each task, the time interval for the performance of the task and the activity time are output. The start time and description of each phase and event are also output. See section 8.4.2.1 for an example. If the report is for the shifted mission scenario, the amount of the shift is also output.

4.3.2.2 Crewman Workload Profile Report

The crewman workload profile report provides a timeline output of the channel activity (percent utilization) by channel and by channel classes (vision, motor, and communication) as well as a weighted average of activity for all channels. See section 8.4.2.2 for an example.

4.3.2.3 Crewman Workload Summary Statistics Report

The crewman workload summary statistics report provides a statistical summary of the channel activity, the channel group activity, and the weighted channel activity over a specified flight phase and for a specified crewman. The report gives for each of these activities, the sum and sum squared of the workload, the average workload, the variance of the workload, and the standard deviation of the workload. See section 8.4.2.3 for an example.

4.3.2.4 Task-Channel Activity Report

The task-channel activity report provides a list of all tasks that contribute to a channel workload exceeding a specified threshold. The report is for a specified crewman, for a specified phase, and for a shifted or unshifted option. See section 8.4.2.4 for an example.

4.3.2.5 Subsystem Activity Report

The subsystem activity report provides a measure of the task-channel workload activity exceeding a specified threshold that is associated with a given subsystem. The report gives measures of this workload relative to study intervals, phase duration, and mission duration. See section 8.4.2.5 for an example.

4.3.2.6 Subsystem Activity Summary Report

The subsystem activity summary report provides a summarization of the subsystem activity report and extends the summary across the entire mission. For each channel

that uses a specified subsystem, the report gives the percent of interval time that a channel workload exceeds the report threshold and the percent of mission duration that a channel workload exceeds the report threshold. See section 8.4.2.6 for an example.

4.3.2.7 Task List Report

The task list report lists tasks, the associated situations, the duration of the task situation, and the channel workloads. It is used only to create a task catalog. See section 8.4.2.7 for an example.

4.3.3 GRAPHICAL PLOTTER OUTPUT

Plotter output consists of the following plots:

1. Workload summary (sec. 8.4.3.3)
2. Channel activity summary (sec. 8.4.3.1)
3. Workload histogram (sec. 8.4.3.2)
4. Mission timeline (sec. 8.4.3.4)

4.3.3.1 Workload Summary

The workload summary plot is a bargraph of comparative workloading of channel groups as well as overall average workloading between two or three configurations for a specified flight phase and specified crewmember. It presents the average workloading and/or the standard deviation for the channel groups, under the specified shifted or unshifted option. See section 8.4.3.3 for an example.

4.3.3.2 Channel Activity Summary

The channel activity summary bargraph presents the percent of workloading and workloading standard deviation of channels and of the weighted channel average workloading for a specified mission, crewmember, flight phase, and shift/unshift option. See section 8.4.3.1 for an example.

4.3.3.3 Workload Histogram

The workload histogram depicts average percent workload versus time in the mission. It can have one, two, or three configurations plotted. The peak workload threshold is shown. See section 8.4.3.2 for an example.

4.3.3.4 Mission Timeline

The mission timeline plot presents the event occurrence and procedure start time, the task activity, and the interval of time the activity is under way. The task/event/procedure code number, task/event/procedure description, and time duration or time of occurrence are shown. See section 8.4.3.4 for an example.

5.0 SCENARIO DERIVATION

5.1 INTRODUCTION

During the creation of TLA-1, eight scenarios were developed to provide a set of baseline missions that are based on flight operations in a real-world terminal area environment. As flight deck configurations and procedures are changed during the TCV program, new factors can be incorporated into the scenarios. The workload data from these new missions can then be compared to the data from the baseline scenarios to determine the relative workload improvements or degradations caused by the changes.

These scenarios were used as example data cases that were fully programmed into TLA-1 coding to demonstrate how TLA-1 input data are to be coded. Processing of these data cases created examples of all TLA-1 output reports and plots. The scenarios were also used as a forcing function to cause the development of a wide range of preprogrammed procedures that provide fully-detailed building blocks from which new TCV scenarios can be constructed. In addition, the scenarios provide the analyst with models of the degree of detail required when constructing new scenarios for TLA-1 analysis.

There are two general categories of scenarios—forward flight deck (FFD) and aft flight deck (AFD)—with four variations for each category. (See table 1.) The scenarios are described in detail in the following sections.

All the scenarios are based on operations within the terminal area of the Hartsfield Atlanta International Airport. The following flight phases are included:

- | | | |
|--------------------|---|--------------------------|
| 1. Prestart | } | Outbound from
Atlanta |
| 2. Startup | | |
| 3. Taxi out | | |
| 4. Takeoff | | |
| 5. Climb-to-cruise | | |
| 6. Cruise | } | Inbound to
Atlanta |
| 7. Descent | | |
| 8. Approach | | |
| 9. Landing | | |
| 10. Taxi in | | |
| 11. Shutdown | | |

Table 1.—Scenario Classification

Scenario name	Features		
	Cockpit	Approach and landing procedures	Anomalies ?
Scenario 1A	FFD	ILS	No
Scenario 1B	FFD	ILS	Yes
Scenario 2A	FFD	MLS	No
Scenario 2B	FFD	MLS	Yes
Scenario 3A	AFD	ILS	No
Scenario 3B	AFD	ILS	Yes
Scenario 4A	AFD	MLS	No
Scenario 4B	AFD	MLS	Yes

The time-based listing of events provided in the scenarios includes the following:

- Taxi maneuvers—before takeoff and after landing
- Noise abatement takeoff
- Aircraft configuration changes during flight
 - Gear extension/retraction
 - Flap extension/retraction
- Horizontal and vertical maneuvers
- Aircraft speed changes
- ATC/pilot communications text
- ATC facility handoff points
- Navaid tuning requirements
- ILS/MLS intercept points
- Landing

The scenarios were derived from data collected during a visit to the Atlanta ARTCC, the Atlanta Tower, and the FAA Southern Regional Office (refs. 5 through 16) and from Boeing 737 aircraft operation and performance manuals (refs. 5 and 17 through 22).

The detailed scenarios are found in Appendices One through Four (ref. 4).

5.2 SCENARIO DESCRIPTIONS

5.2.1 SCENARIO 1A

Scenario 1A is based on the NASA 515 FFD and conventional ATC procedures and nav aids. The horizontal profile is shown in figure 11, and the vertical profile is shown in figure 12. The detailed scenario is in Appendix One (ref. 4).

In this and all the other scenarios, the aircraft is parked at a gate at the northeast side of the Atlanta Airport terminal (fig. 13). After pushback and startup, the aircraft taxis across the apron to Taxiway D. Ground Control instructs NASA 515 to hold short of Runway 8 to allow arrival and departure traffic to clear. After the traffic is cleared, the pilot is given clearance to taxi across Runway 8 and is again instructed to hold short of the intersection of Taxiway C to allow traffic to cross. The aircraft then proceeds to Taxiway L and onto Runway 9L where it is cleared for takeoff. The aircraft turns to heading 105 after crossing the Runway 27R middle marker (fig. 14). This is the noise abatement track for Runway 9L departures.

Standard IFR Scenario—ILS Approach,
Horizontal Profile

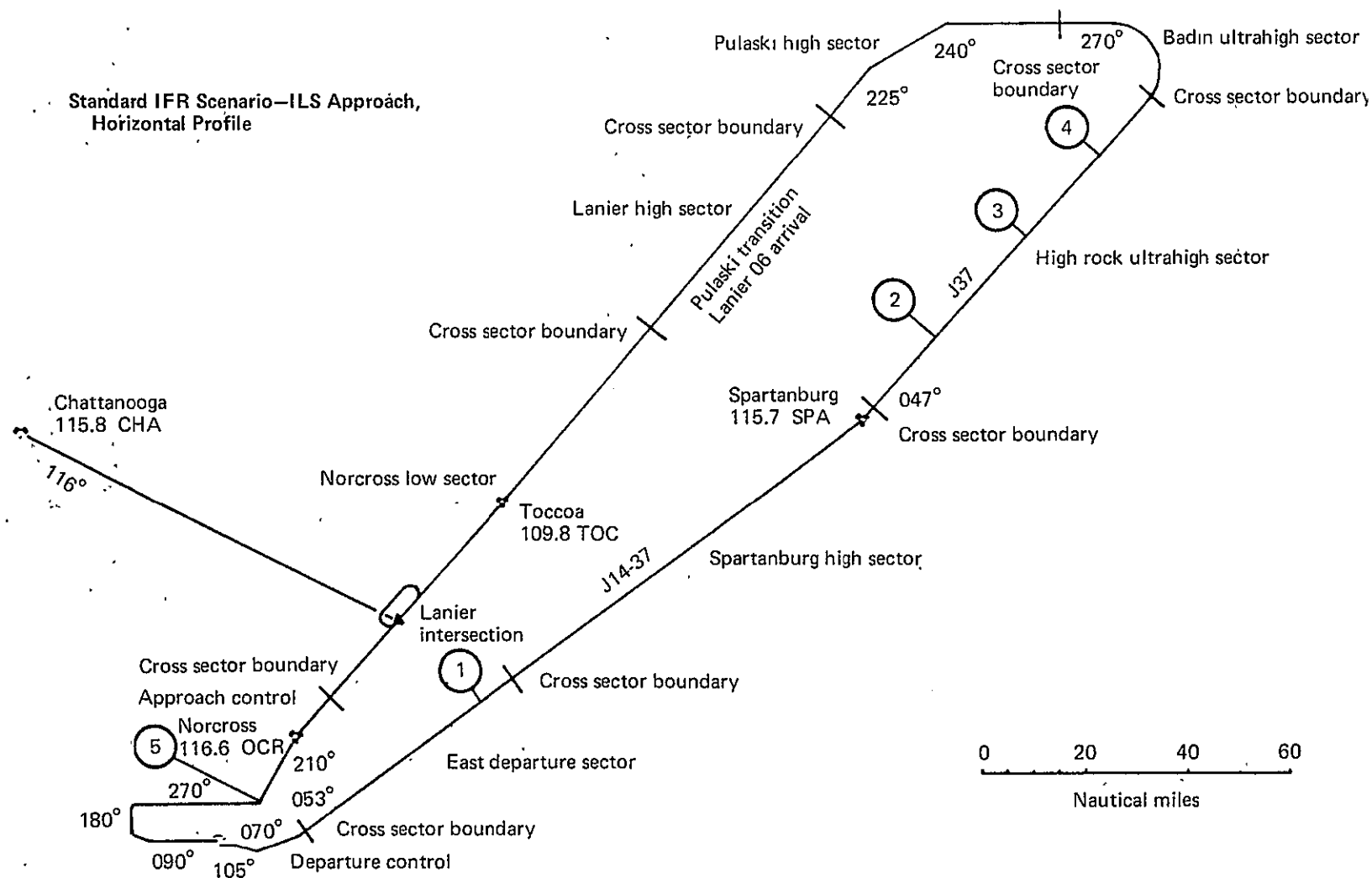


Figure 11.—Horizontal Mission Profile for Scenarios 1A and 1B

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Standard IFR Scenario—ILS Approach,
Vertical Profile

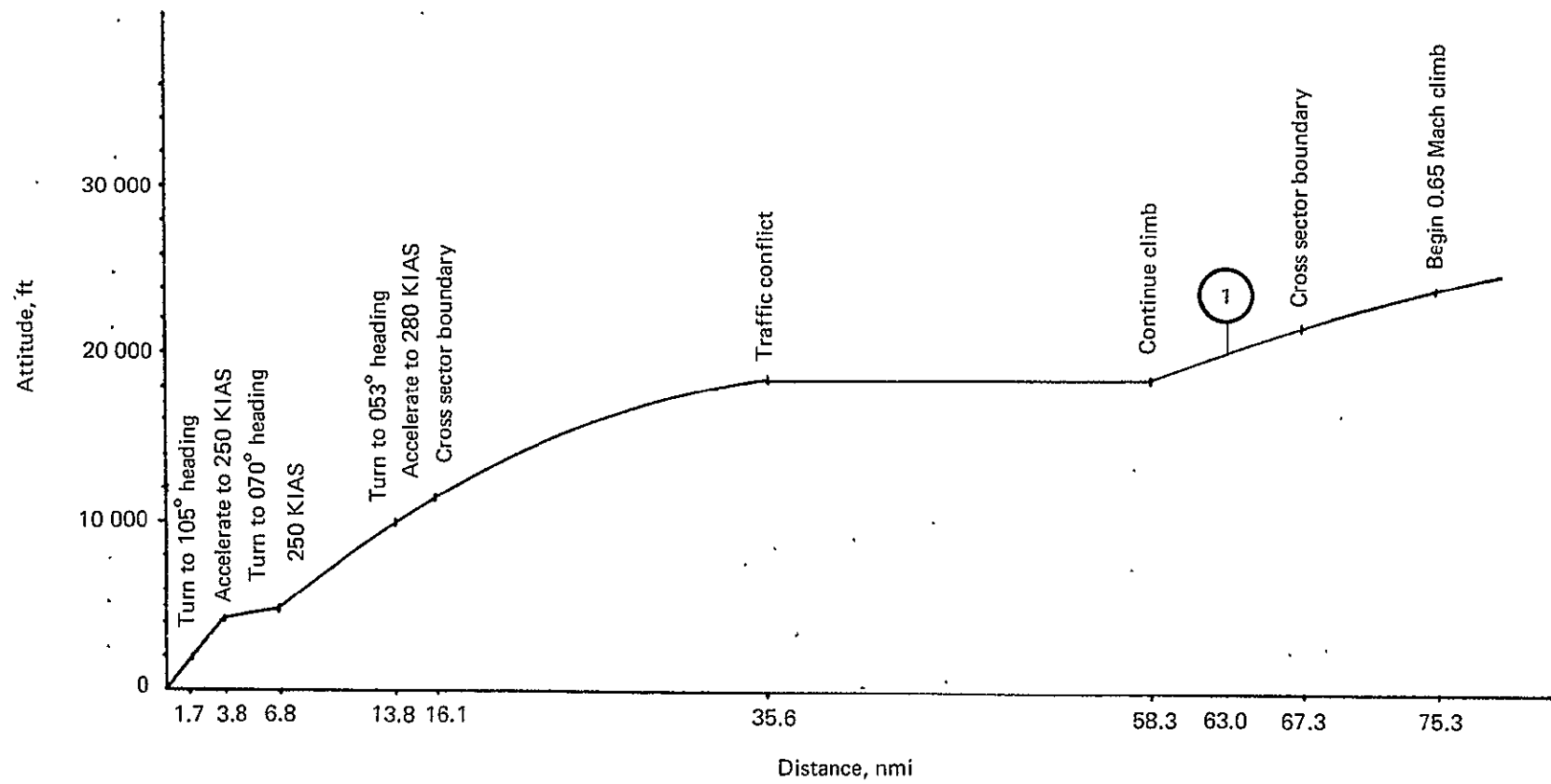


Figure 12.—Vertical Mission Profile for Scenarios 1A and 1B

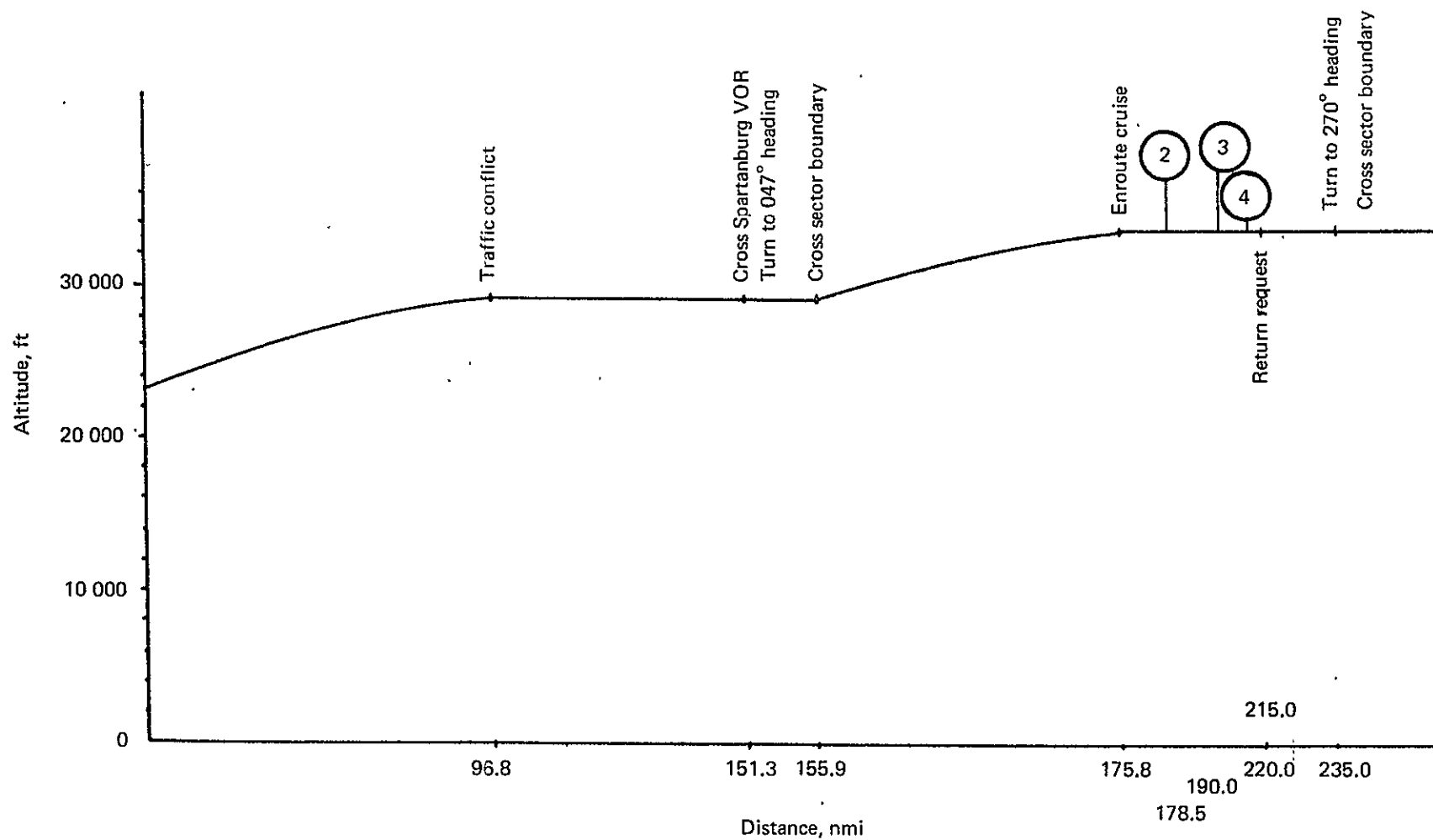


Figure 12.—(Continued)

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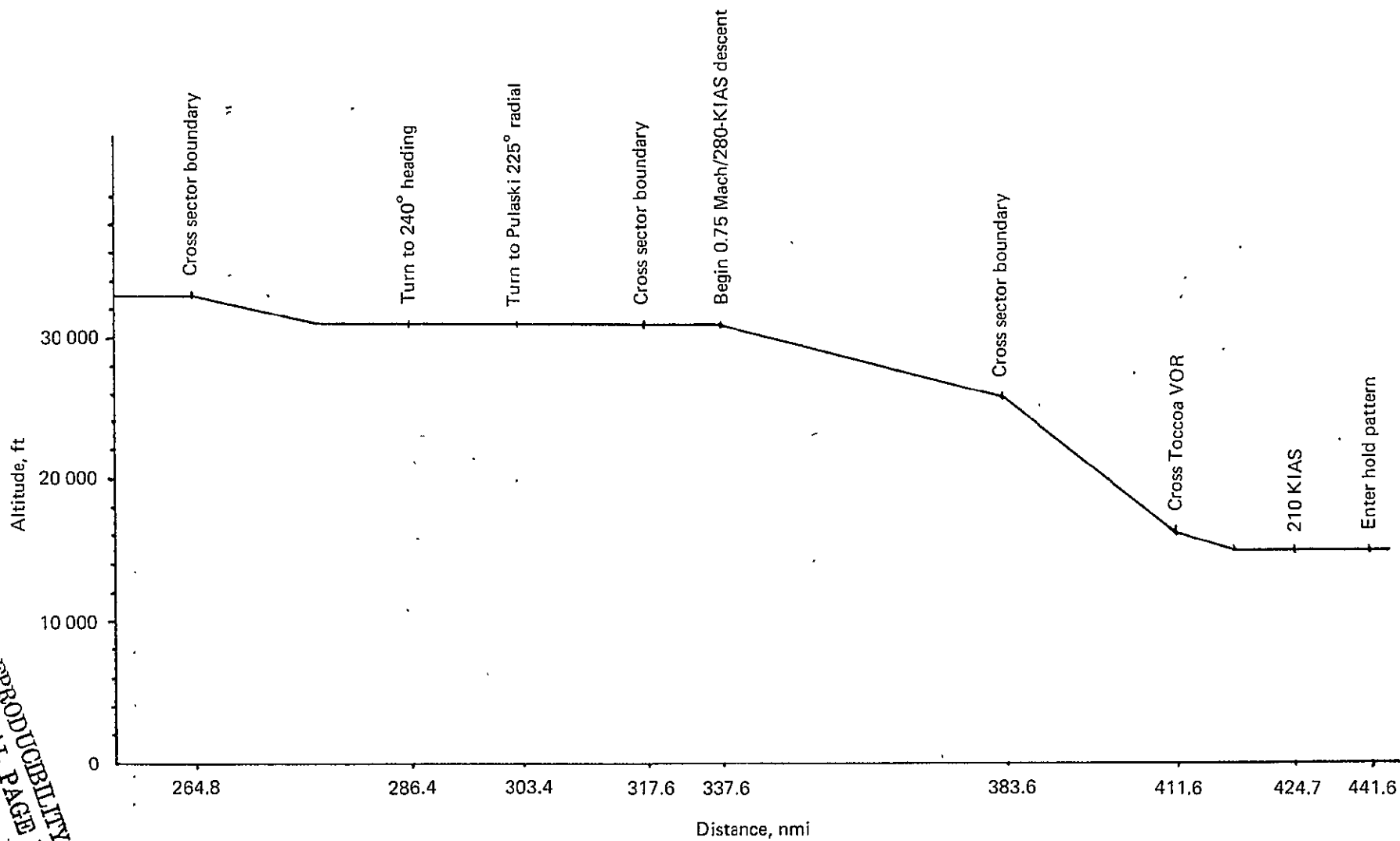


Figure 12.—(Continued)

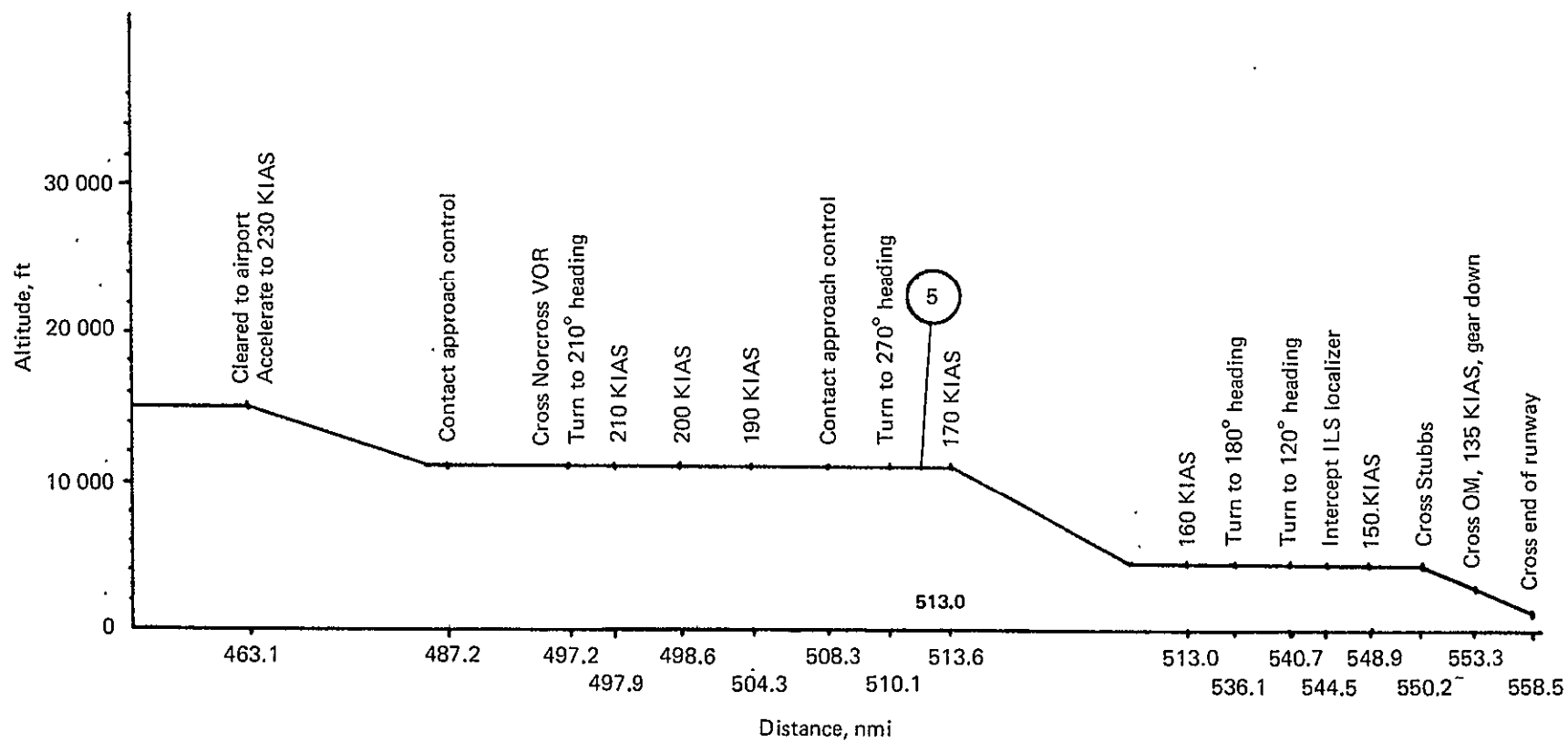


Figure 12.—(Concluded)

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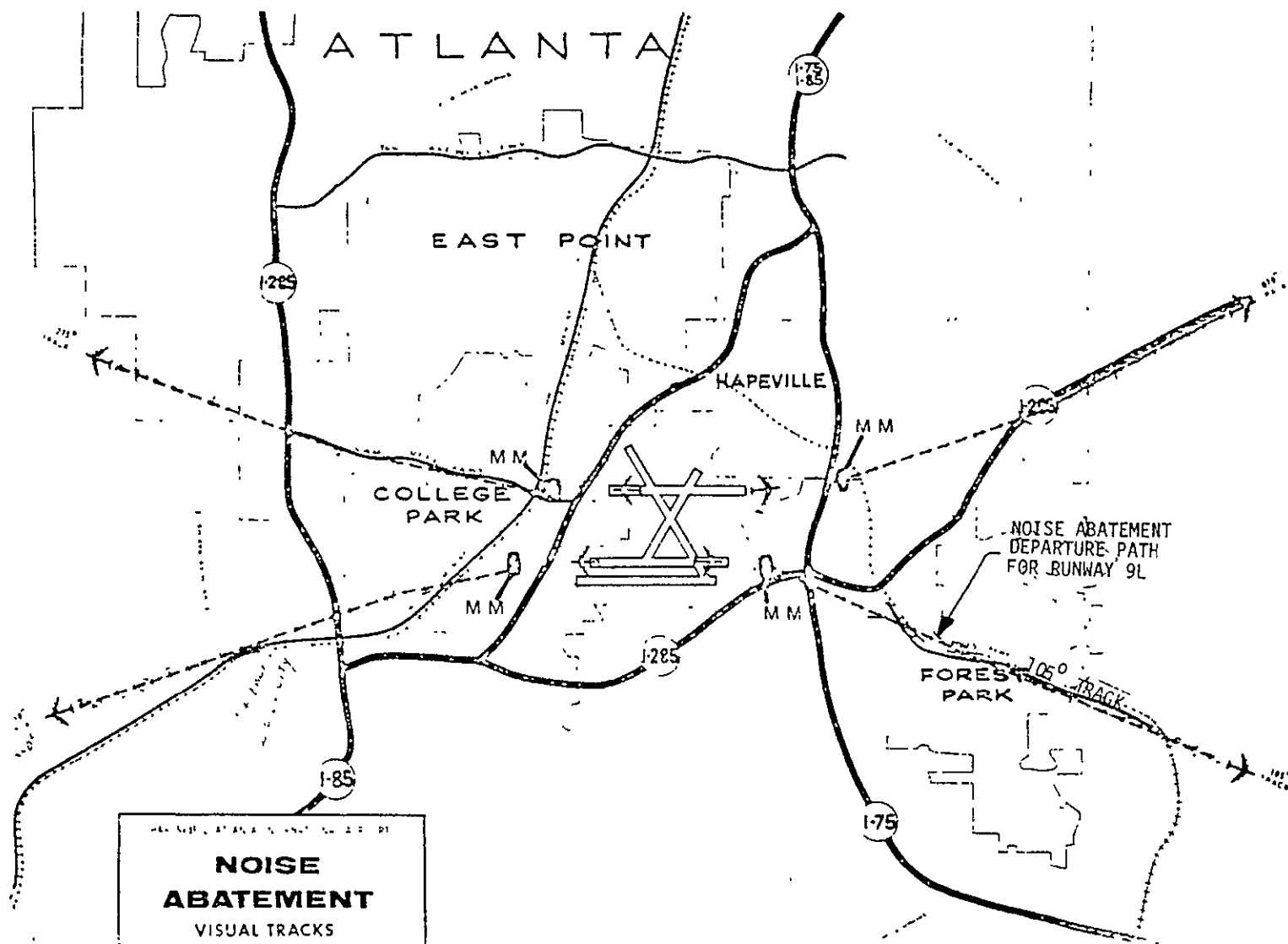


Figure 14.—Noise Abatement Departure Path for Runway 9L

Scenarios 1A, 1B, 2A, and 2B proceed as follows. After reaching 4000 feet, NASA 515 is given vectors to intercept Jet Route 37. En route to cruise altitude, NASA 515 is directed to hold FL 180 to avoid crossing inbound traffic. The aircraft then resumes climbing to FL 330, the en route cruise altitude.

After reaching cruise altitude, the pilot requests a return routing to Atlanta. In scenarios 1A and 2A, this request was put into the scenario to keep the area of study confined to the Atlanta terminal area. In scenarios 1B and 2B, a series of malfunctions will create a definite need for the aircraft to return to Atlanta (secs. 5.2.2 and 5.2.4).

For return routing to Atlanta, ATC gives NASA 515 vectors to intercept the Lanier 06 STAR (fig. 15). While on approach, NASA 515 is instructed to go into a holding pattern. In scenarios 1A and 1B, the final approach is via the conventional ILS procedures for Runway 8.

In all of the scenarios, NASA 515 lands on Runway 8 and departs the runway onto Taxiway D. The aircraft returns to its departure gate and the aircraft is shut down.

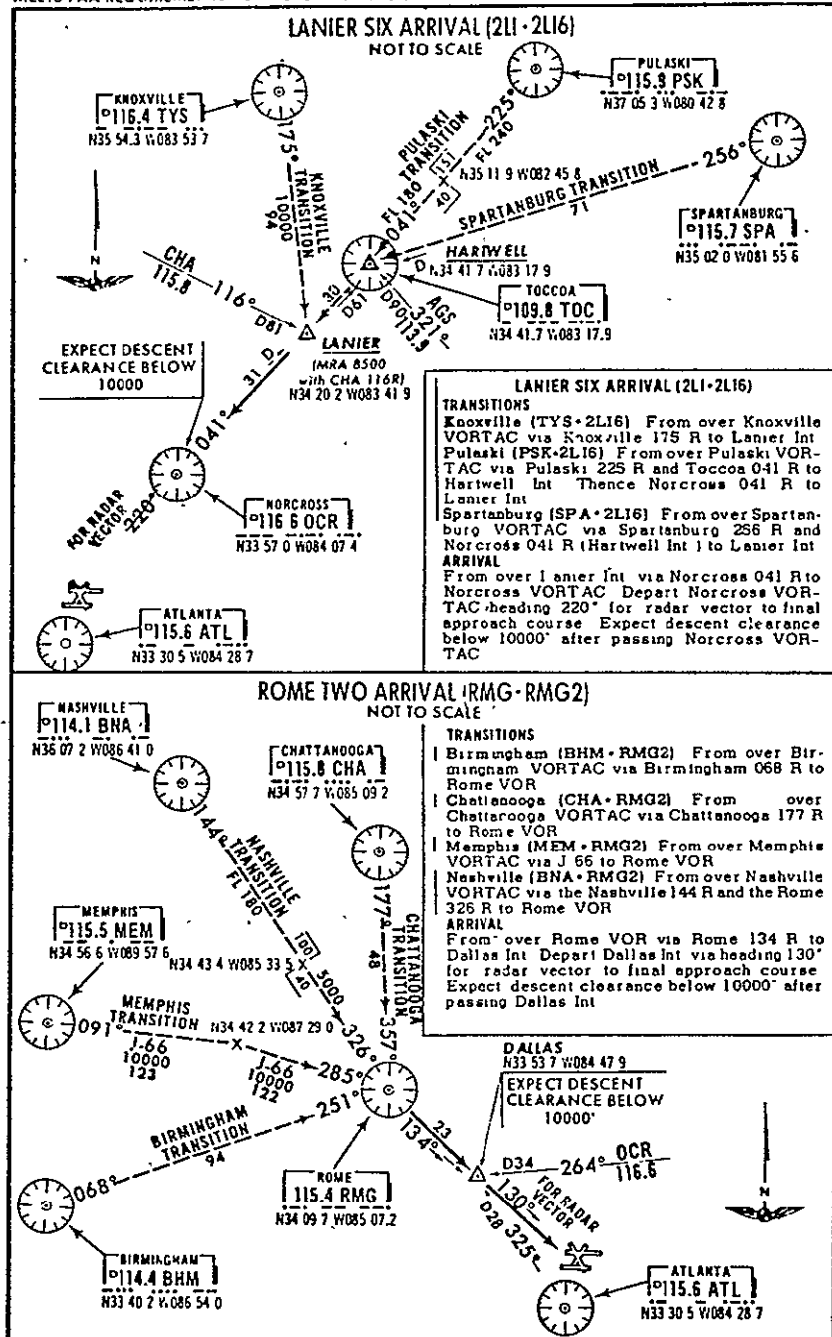
5.2.2 SCENARIO 1B

Scenario 1B is based on the FFD and conventional ATC procedures and nav aids. This scenario is basically the same as scenario 1A except that on this flight there is a series of malfunctions and the pilot is incapacitated.

Figures 11 and 12 have circled numbers to show the points on the flightpath where the various anomalies occur and the types of anomalies. The anomalies are:

Occurrence	Type	Where anomaly occurs
①. Hydraulic system B overheat	Hydraulic system failure	During climb
②. Hydraulic system B low pressure	Flight control failure	During cruise
③. Oil filter bypass	Engine failure	During cruise
④. No. 2 generator drive CSD low oil pressure	Electrical system failure	During cruise
⑤. Pilot incapacitation	Crewmember incapacitation	Prior to final approach

These anomalies are used in scenarios 1B, 2B, 3B, and 4B. The details of scenario 1B are in Appendix One (ref. 4).



CHANGES Lanier and Rome Arrivals.

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Figure 15.—Lanier 06 STAR

5.2.3 SCENARIO 2A

Scenario 2A is based on the FFD and on microwave landing system (MLS) approach and landing. This scenario is identical to scenario 1A from the beginning up to the point where the aircraft starts down the downwind leg on final approach. In scenario 2A, the final approach is based on MLS landing procedures on Runway 8. Figure 16 shows the horizontal profile, and figure 17 shows the vertical profile. The details of this scenario are in Appendix Two (ref. 4).

The MLS provides flight director glide slope and direction commands starting at 60° angle from the runway threshold. Subsequently, the downwind leg of the approach is considerably shorter than on an ILS approach. After capture of the MLS signal, the MLS procedure postulated involves a two-segment glidepath (6° initial and 3° final glide slopes).

5.2.4 SCENARIO 2B

Scenario 2B is identical to scenario 2A except for the addition of the series of anomalies described in scenario 1B (sec. 5.2.2). Figure 16 shows the location and nature of the anomalies on the horizontal profile map. Details of this scenario are in Appendix Two (ref. 4).

5.2.5 SCENARIO 3A

Scenario 3A and scenarios 3B, 4A, and 4B are based on the AFD and on advanced navigation concepts structured around existing RNAV routing between Atlanta and Washington, D.C.

To develop realistic scenarios for exercising the AFD instrumentation, it was necessary to make some assumptions concerning: (1) the state of the art for ATC and nav aids, (2) the automatic guidance modes to be used, and (3) the flight plan data available in the aircraft's data bank. The following assumptions were made:

1. All SID's, STAR's, and AIRWAYS for the Atlanta terminal area are stored in memory.
2. The SID's and STAR's are based on existing RNAV routes in the area.
3. The SID's and STAR's will include new waypoints where required to replace ATC vectoring commands.
4. After takeoff clearance, the only ATC commands transmitted will be handoff instructions or instructions for controlling potential conflicts or unusual situations.
5. ATC will have the means required to compute valid planned time of arrival (PTA) at the final approach fix point.
6. Lakeside LOM will be the final approach fix point for Runway 8 arrivals.

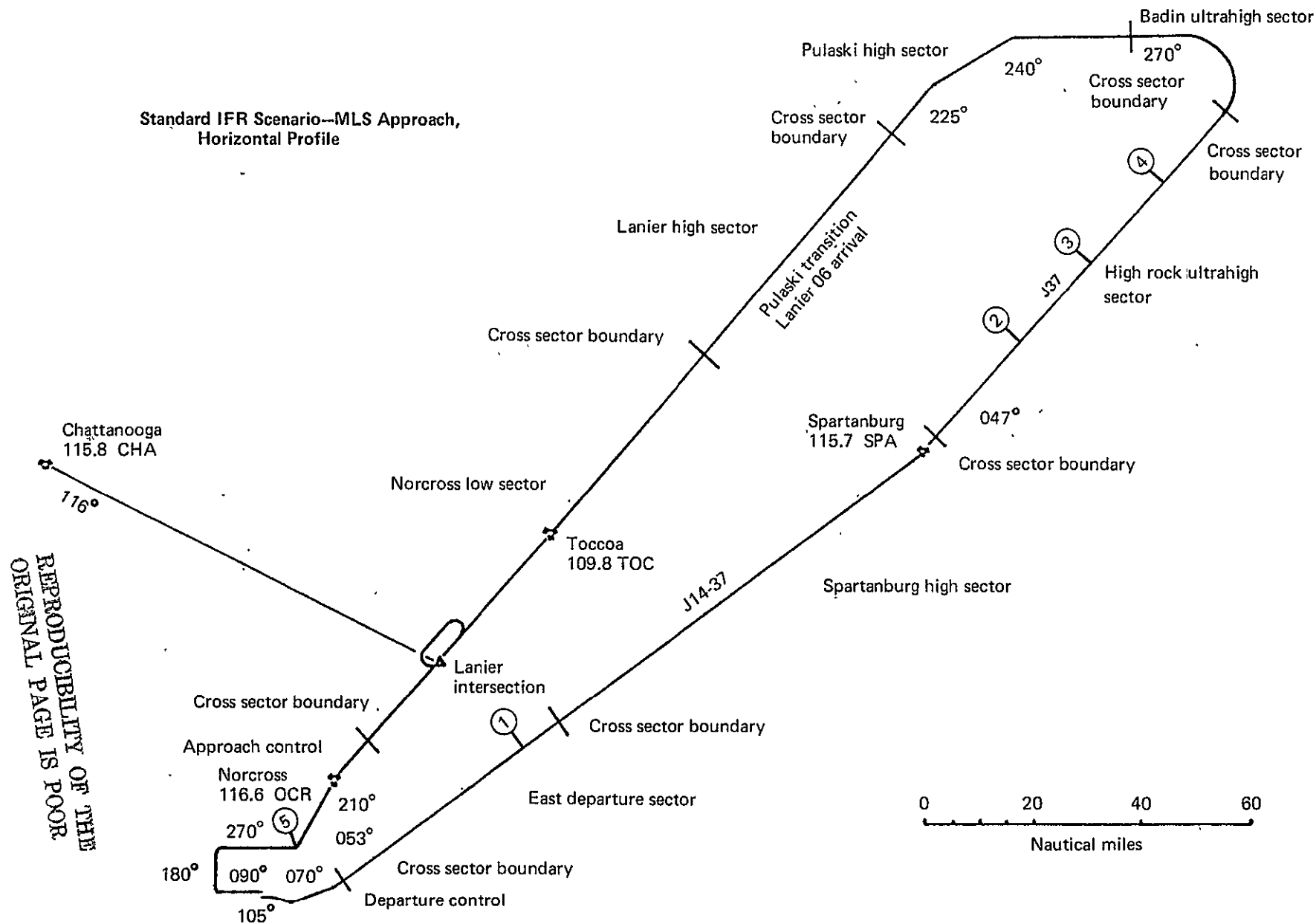


Figure 16.—Horizontal Mission Profile for Scenarios 2A and 2B

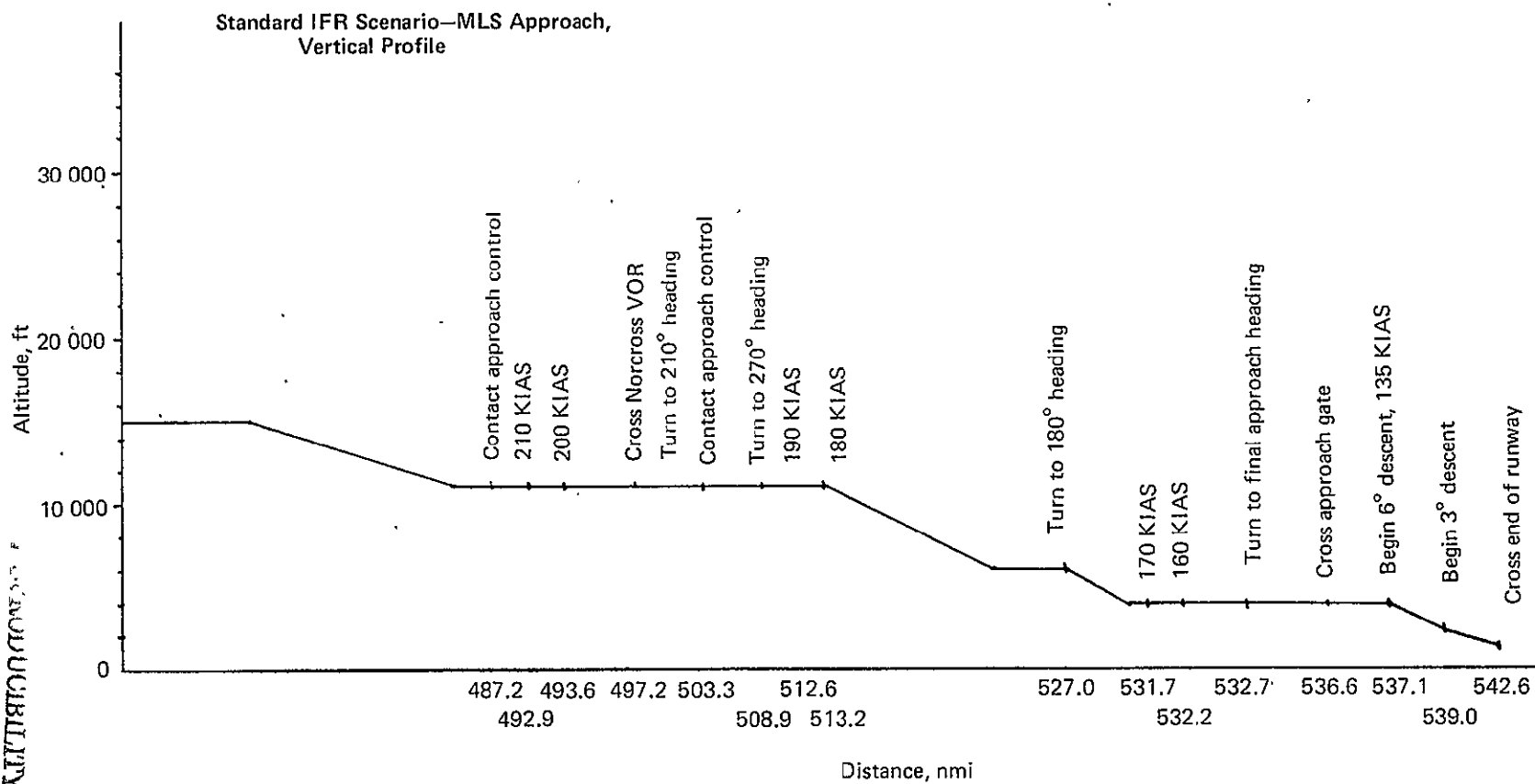


Figure 17.—Vertical Mission Profile for Scenarios 2A and 2B

7. The SID's, STAR's, and navaid names will be revised as required to keep the name character lengths compatible with the current NASA 515 programming requirements.
8. Takeoff will be done in the ATT CWS mode.
9. The climb-to-cruise flight phase will be done in the 3D (vertical path) mode. This assumes that a valid 3D path can be predefined.
10. When the aircraft diverts from the preplanned routing, control will be in the 2D (horizontal path) mode.
11. The STAR will be flown in the 4D (time path) mode. This assumes that a valid 4D path can be defined.
12. The STAR 4D data will be computed by ATC within 3 to 5 minutes from request.

The horizontal profile for scenario 3A is shown in figure 18, and the vertical profile is shown in figure 19. Details of this scenario are in Appendix Three (ref. 4).

The on-ground portion of scenario 3A is almost identical to that described for scenario 1A, the only variations being in the communications dialog.

The en route navigation is prestored in the aircraft's computer based on departure waypoints. The routing to Washington National is based on the existing J86R RNAV route.

The aircraft is flown on a 3D profile on departure. The only ATC communications are to hand off and to instruct NASA 515 to level off during climb to avoid conflicting traffic. After passing the conflict, the aircraft is flown 3D to get back on the prestored flight plan. After reaching cruise altitude of 33 000 ft, the pilot requests an unscheduled return to Atlanta.

After giving initial vectors to start the return routing to Atlanta, ATC gives NASA 515 instructions to return via the SHINE 01 STAR, which is preprogrammed in memory, and a PTA at Lakeside is given. The pilot selects the appropriate 4D path and initiates the 4D navigation procedures. On the way back, ATC gives NASA 515 a new PTA.

The approach is based on the same ILS approach used in scenario 1A. The pilot elects to use the AUTOLAND mode for the landing. After touchdown, the scenario is identical to that described for scenario 1A.

5.2.6 SCENARIO 3B

Scenario 3B is basically the same as scenario 3A except that the same series of anomalies described for scenarios 1B and 2B is imposed. Figure 18 shows the horizontal profile for this scenario. Details of scenario 3B are in Appendix Three (ref. 4).

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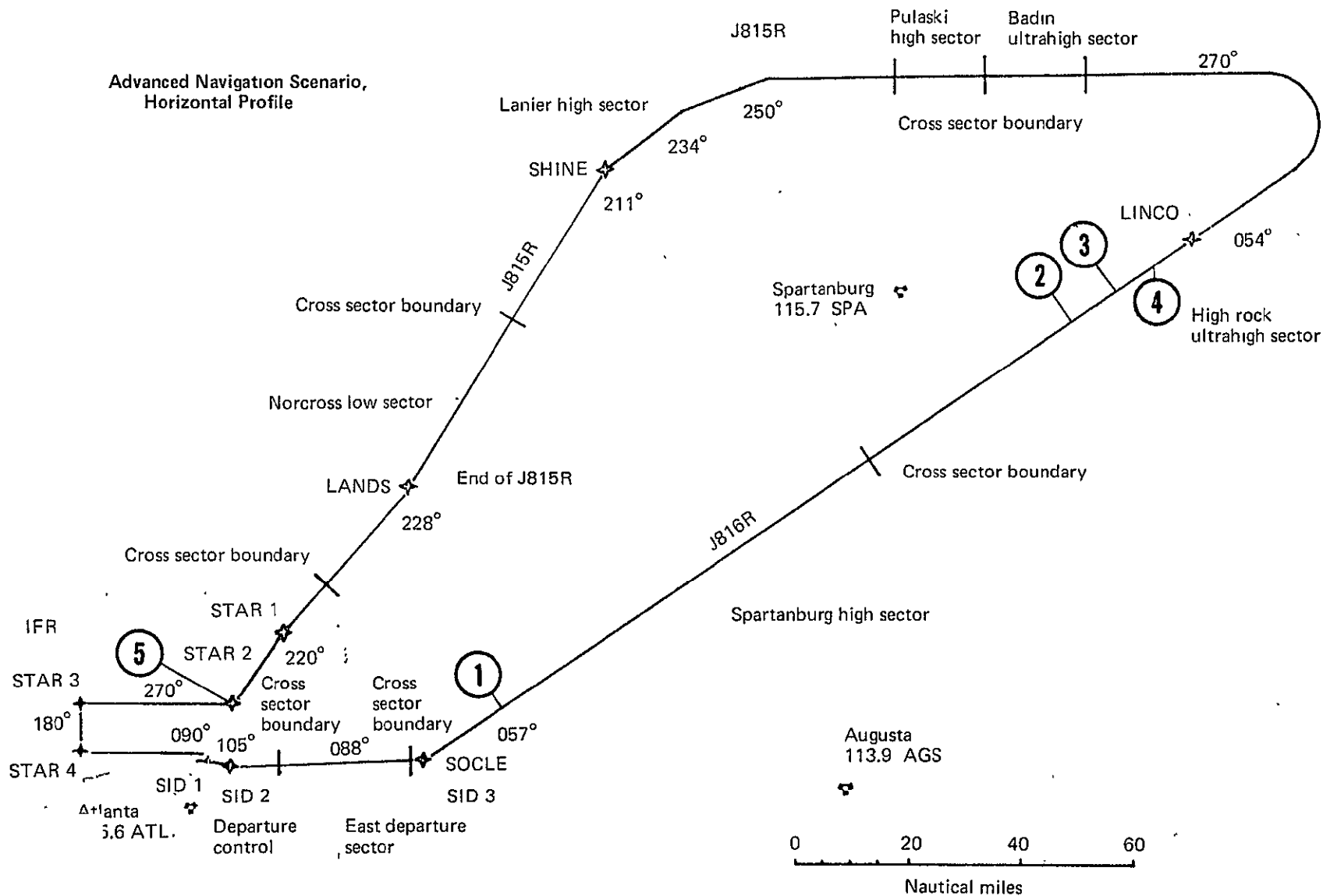


Figure 18.—Horizontal Mission Profile for Scenarios 3A and 3B

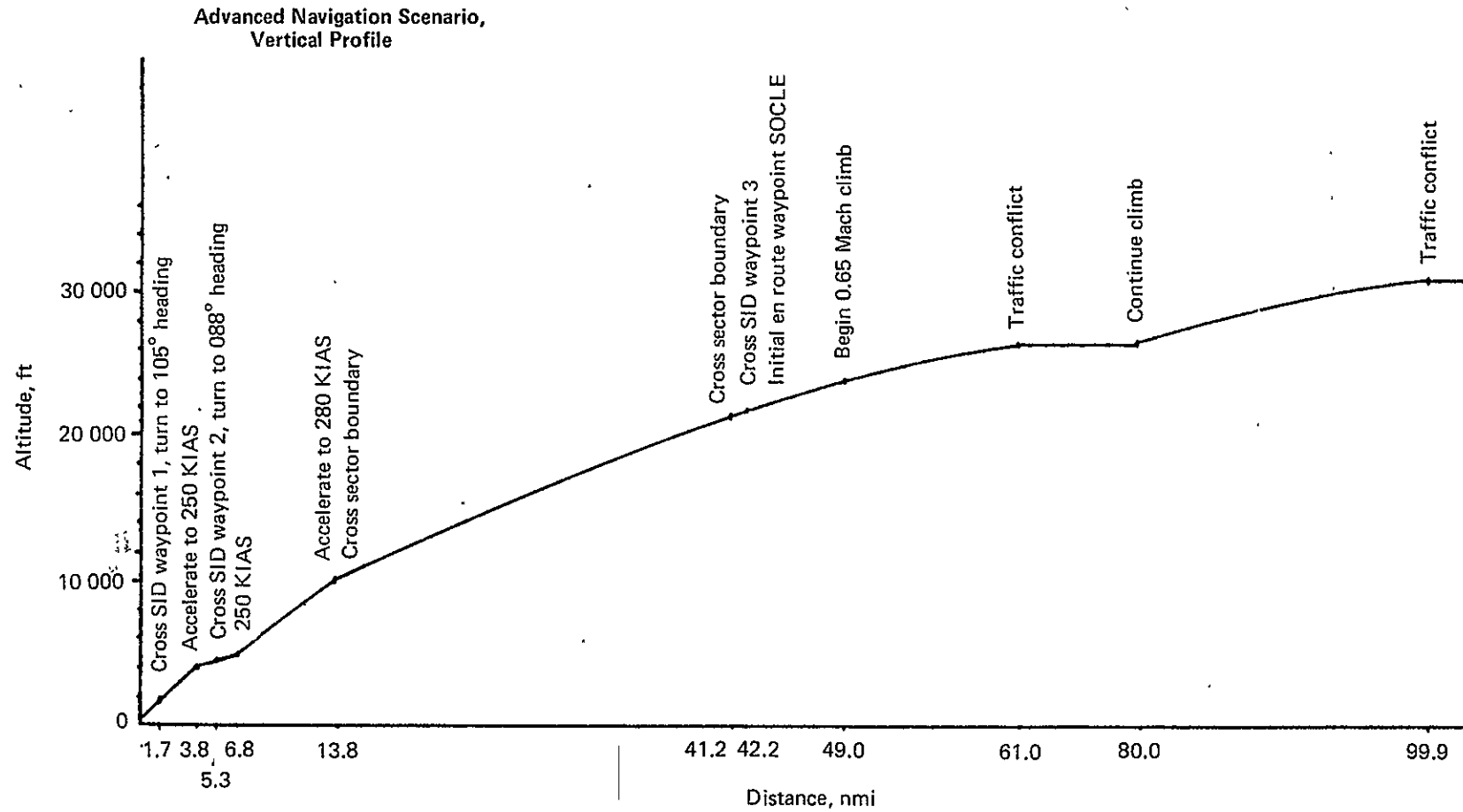


Figure 19.—Vertical Mission Profile for Scenarios 3A and 3B

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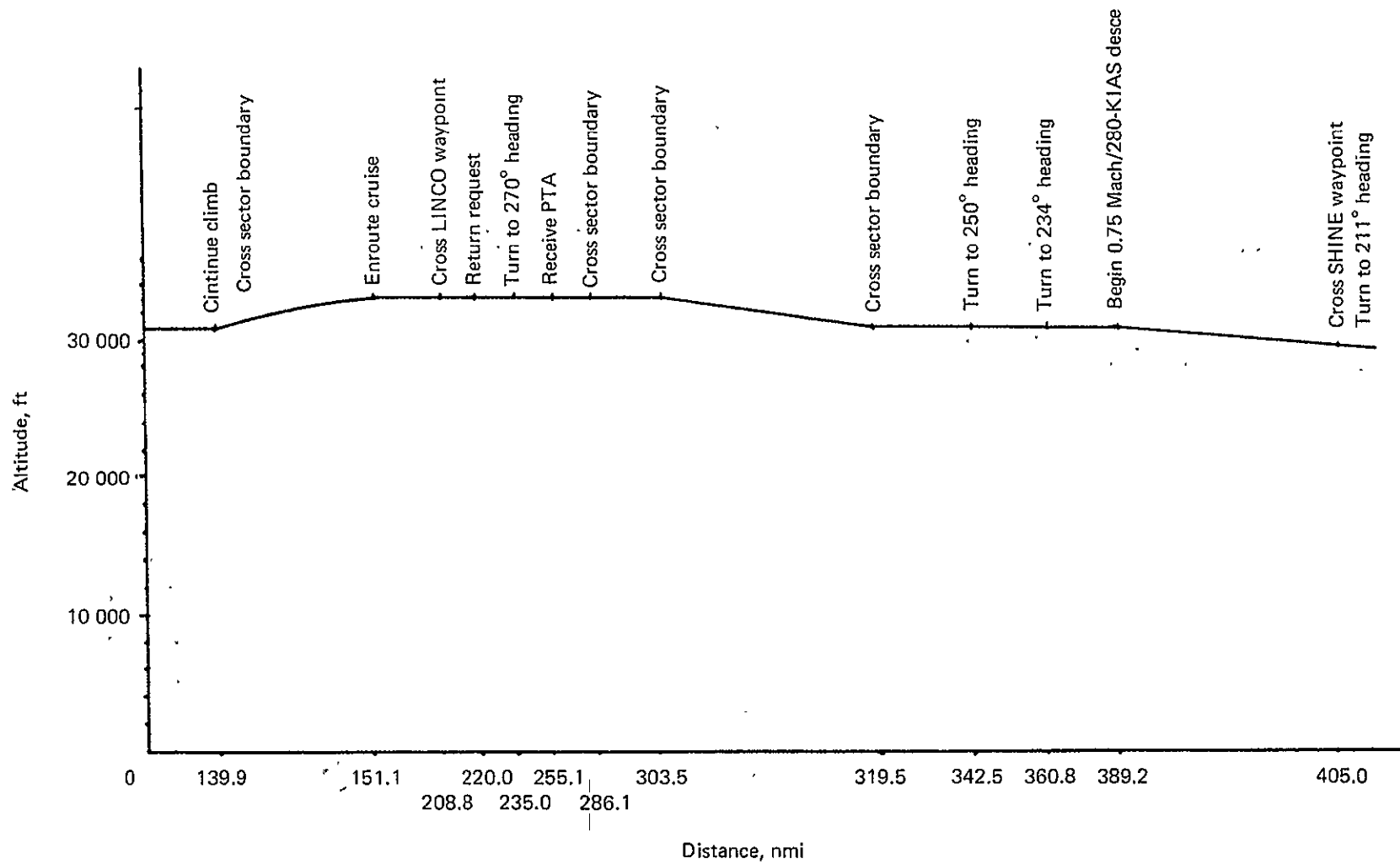


Figure 19.—(Continued)

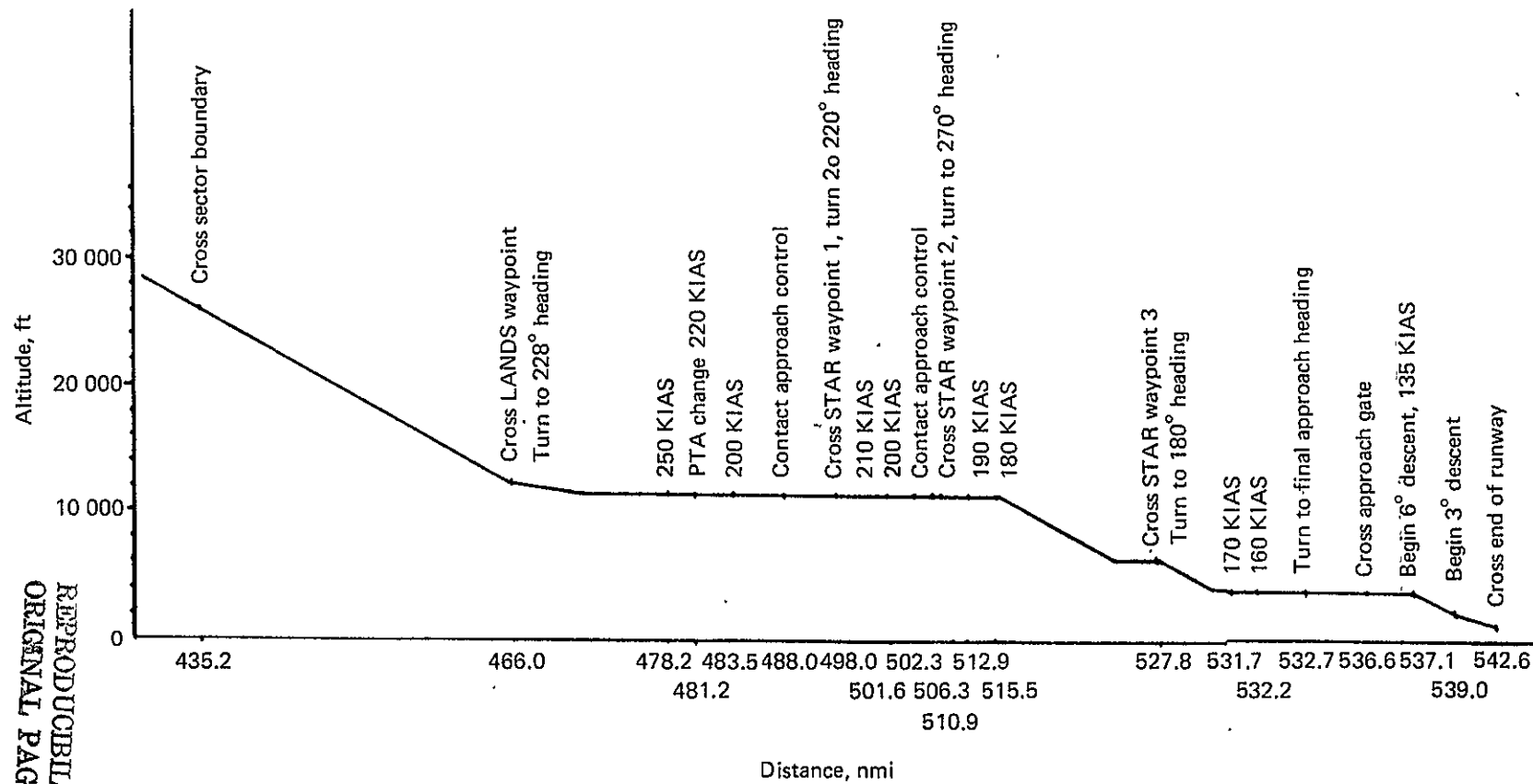


Figure 19.—(Concluded)

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5.2.7 SCENARIO 4A

Scenario 4A is identical to scenario 3A up to the point where the aircraft begins the downwind leg. From this point on, the approach and landing are based on an MLS system. After touchdown, this scenario is identical to scenario 3A. The horizontal profile for this scenario is shown in figure 20, and the vertical profile is shown in figure 21. Details of scenario 4A are in Appendix Four (ref. 4).

5.2.8 SCENARIO 4B

Scenario 4B is identical to scenario 4A except that the series of anomalies used in scenarios 1B, 2B, and 3B is also imposed here. The horizontal profile of this scenario is shown in figure 20. Details of this scenario are in Appendix Four (ref. 4).

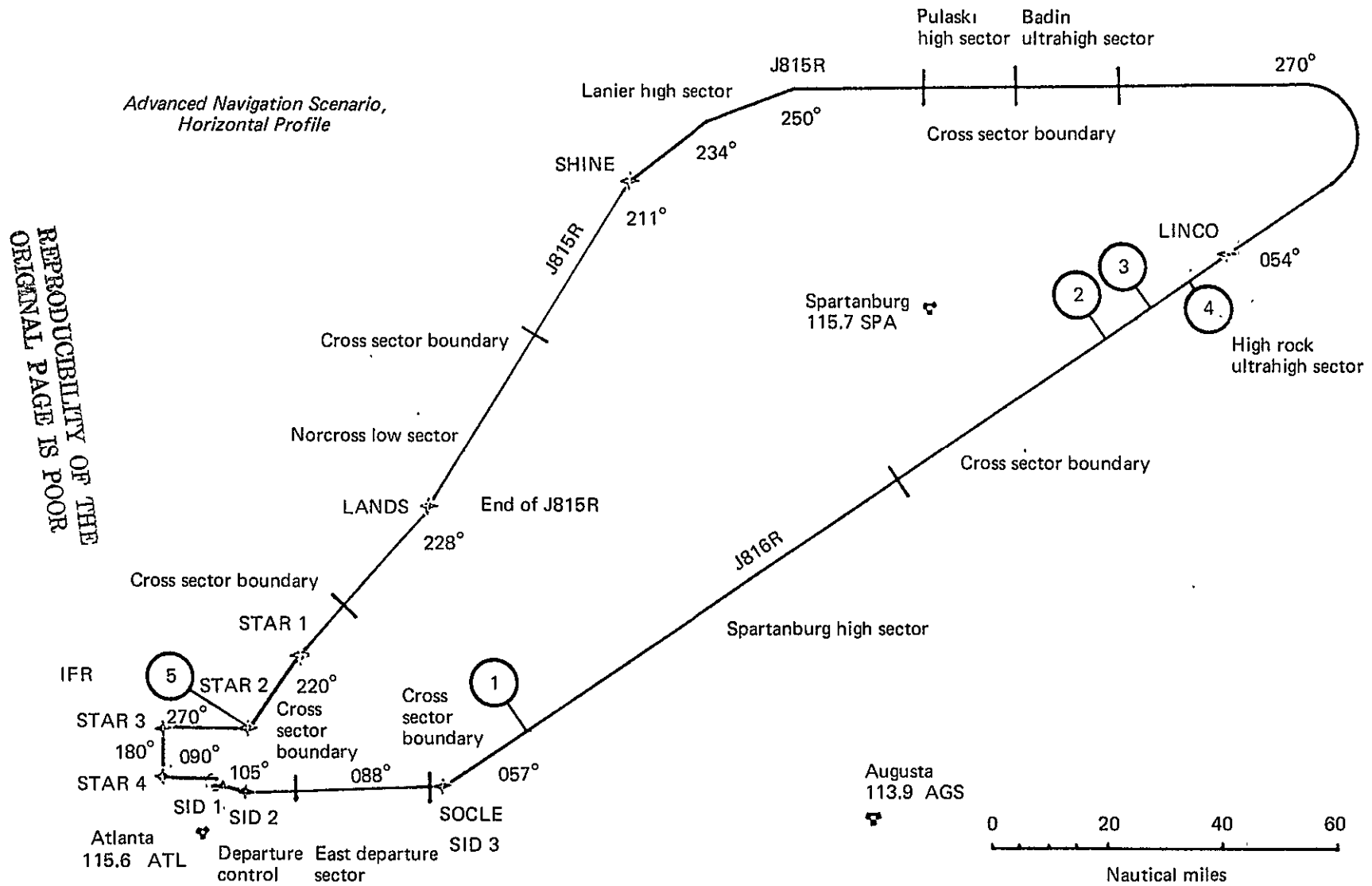


Figure 20.—Horizontal Mission Profile for Scenarios 4A and 4B

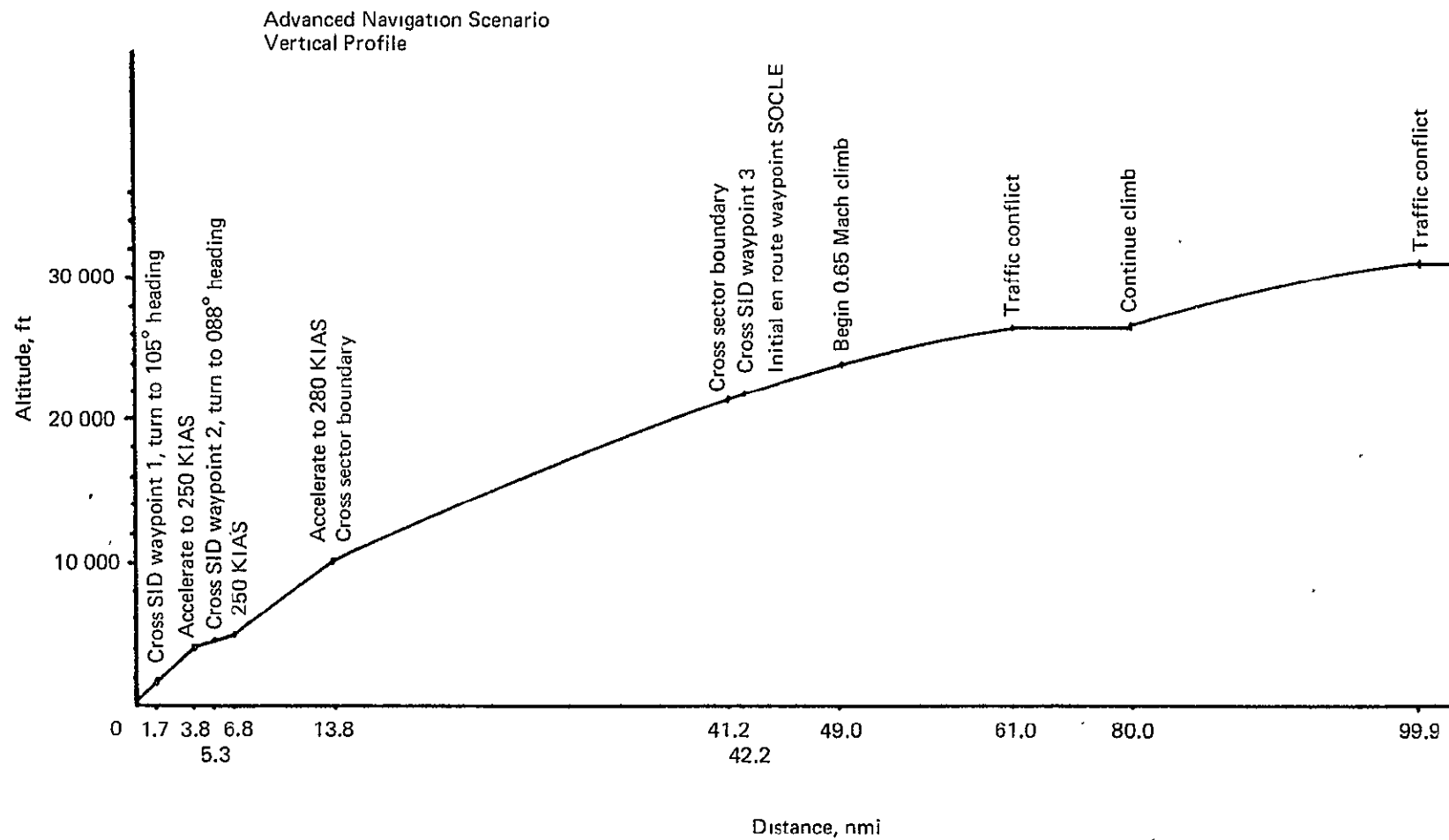


Figure 21.—Vertical Mission Profile for Scenarios 4A and 4B

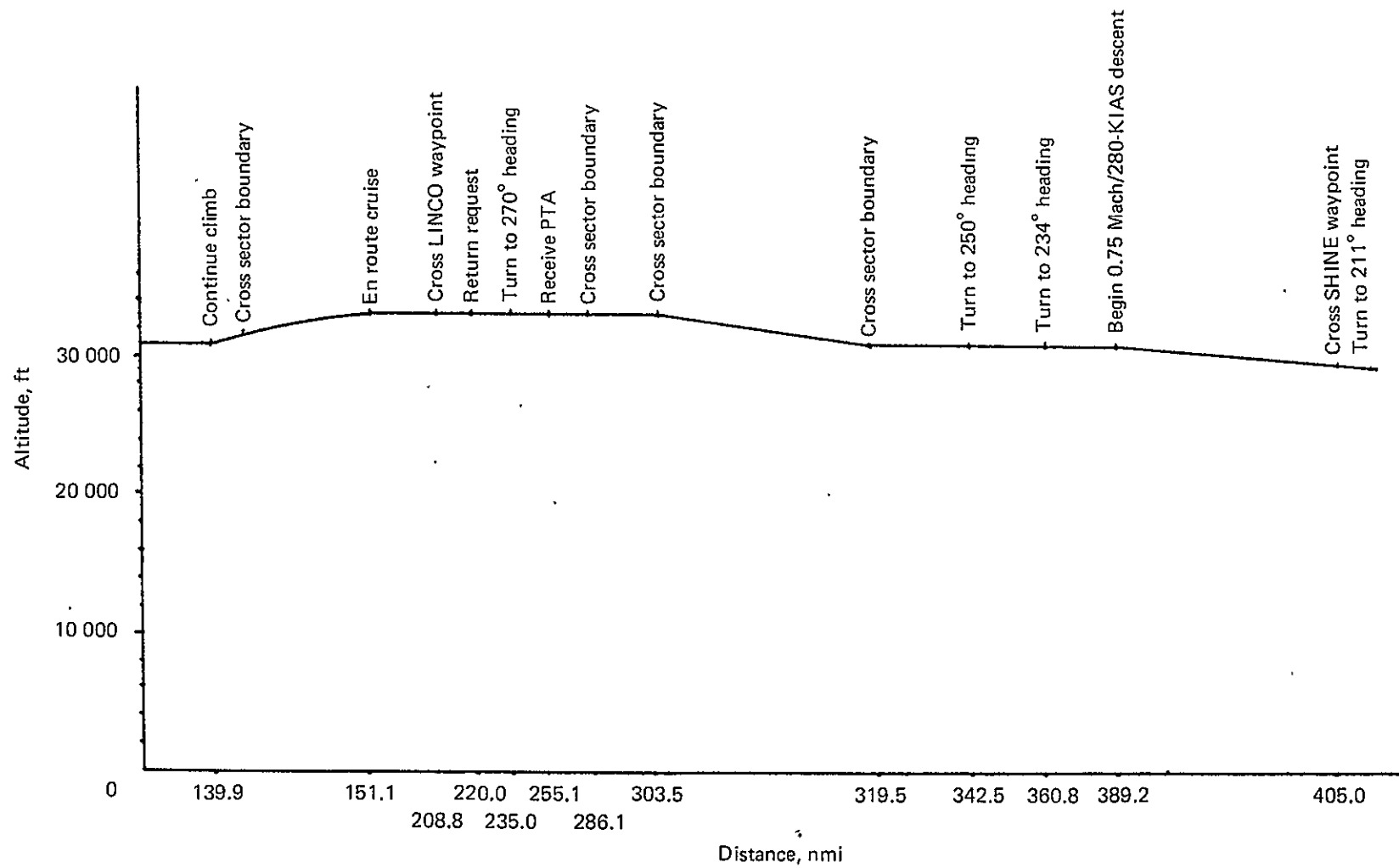


Figure 21.—(Continued)

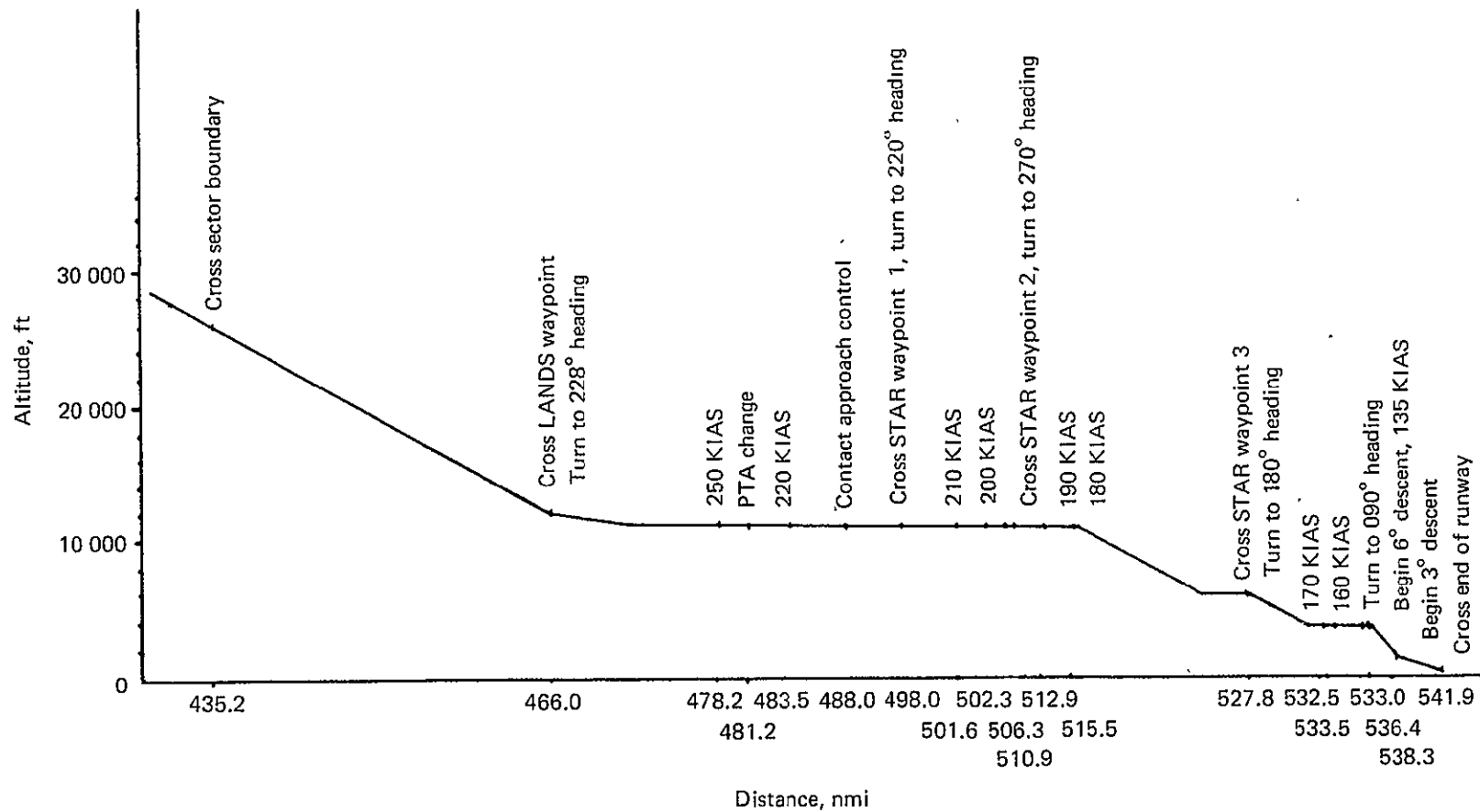


Figure 21.—(Concluded)

6.0 TASK DERIVATION

6.1 INTRODUCTION

In TLA-1, tasks are used as the basic work units from which all crew workload statistics are derived. The level of detail to which the tasks must be defined is described in section 6.3.

Tasks have been identified and cataloged for virtually every control and display in the NASA 515 FFD and AFD. In addition, tasks have been defined for every verbal communication required during an entire flight for all the scenarios described in section 5.0. Tasks have also been defined for all crew actions that are required in the flight but do not fit into the preceding categories. Altogether, over 2000 tasks have been identified and entered into a "Task Catalog for the NASA 515." (See App. Five, ref. 4.)

The TCV program analysts who use TLA-1 will use this task catalog to construct the procedures associated with the test flight scenarios to be analyzed. The analyst will add to the catalog to fill in missing or new tasks as they are identified.

Figure 22 shows a typical page from the task catalog. Each task is totally described by the following fields of data:

<u>Field of data</u>	<u>Column</u>	<u>Explanation of derivation</u>
Task code	1-8	Section 6.3
Task name	10-29	Section 6.3
Situation	31	Section 6.5
Duration time	33-37	Section 6.4
Channel activity	39-74	Section 6.6

6.2 COCKPIT INSTRUMENTATION CONFIGURATIONS

Tasks have been defined for specific NASA 515 FFD and AFD control and display configurations. The configurations used in this study are described in this section.

6.2.1 FORWARD FLIGHT DECK

The FFD instrumentation configuration used in this study was taken from reference 18 and updated to reflect the actual configurations observed on NASA 515 in February 1975. In order to provide a more realistic conventional 737 cockpit configuration for comparison with the advanced AFD cockpit configuration, all controls and displays whose sole purpose was to provide interfaces with the AFD were ignored.

The control and display configurations for the NASA 515 FFD used in the derivation of tasks are shown in Appendix Six (ref. 4).

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BOEING
TLA-1
TASK DATA CODING FORM

PROGRAM	PAGE	OF
PROGRAMMER	DATE	

TASK CODE NO.		TASK NAME AND/OR DESCRIPTION	DURATION TIME (SEC CODES)	CHANNEL ACTIVITY - PERCENT OF DURATION TIME										
BURSTS				EV	IV	LH	RH	LF	RF	COG	AUD	VBL		
7A	28	ACTIVATE ANNUN PNL	1	2.28		100	100					20		
		RECALL SW	2	1.93		100	100					20		
7A	29	CHECK SYS B	1	.90		100						20		
		SW'S OFF	2	1.52		100						20		
7A	30	CHECK ENG NO. 1 SYS A	1	1.36		100						20		
		HYD PUMP SW SET TO ON												
7A	31	CHECK ENG NO. 2 SYS A	1	.75		100						20		
		HYD PUMP SW SET TO ON												
7A	32	MON HYD SYS SW'S	1	2.0		100						20		
7A	33	MON MASTER CAUTION	1	.70		100						20		
		AND ALL ANNUN PNL	2	.54		100						20		
		LTS ILLUMINATED												
7A	34	SET GROUND INTER-	1	1.48		100	100					20		
		CONNECT SW TO OPEN	2	2.58		100		100				20		
7A	35	SET GROUND INTER-	1	1.48		100	100					20		
		CONNECT SW TO CLOSED	2	2.58		100		100				20		
7A	36	MON ALL ANNUN LTS	1	.53		100						20		
		OFF												

Figure 22.—Task Data Coding Form—Example

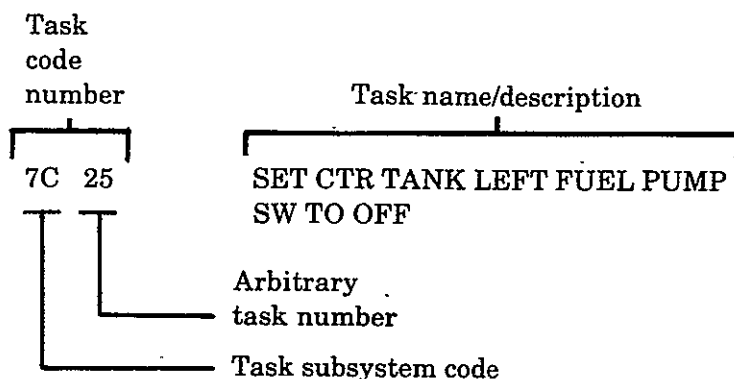
6.2.2 AFT FLIGHT DECK

The AFD instrumentation configuration was taken from reference 23 and updated to reflect the actual configuration observed on the NASA 515 in February 1975. For the reasons explained in section 6.2.1, all controls and displays that were used to interface with the FFD were ignored. In addition, it was assumed that all controls and displays in the AFD were operational.

The control and display configurations for the NASA 515 AFD used in the derivation of tasks are shown in Appendix Seven (ref. 4).

6.3 DERIVATION OF TASK NAMES AND TASK CODE NUMBERS

Each task is given a name and task code number as shown in the following example.



The first two characters in the task code are a subsystem code and the second set of characters is an arbitrary task number (see sec. 6.3.1.) The task name specifies the action taken (SET, ADJUST, MONITOR, etc.), the subject (the control, display, verbal, or auditory item), and, when appropriate, the exact position of a control or display element. (See secs. 6.3.2 and 6.3.3.)

6.3.1 TASK CODE NUMBERS

The TLA-1 tasks are categorized by subsystems. The subsystem categories are listed in table 2 and in Appendix Eleven (ref. 4). Each subsystem category is given a two-character alphanumeric code. The subsystem code is always the first two characters of a task code. An arbitrary task number was assigned to each task as it was taken from the various references. The sequence of task numbers is in no way related to the order of appearance in procedures. Up to six characters are allowed for each task number.

6.3.2 CONTROL-RELATED TASKS

Every control shown on the FFD and AFD panels has one or more tasks associated with it. (See sec. 6.2 and Apps. Six and Seven of ref. 4.) Table 3 lists the various types of

Table 2.—Subsystem Categories

Communications

1A VHF-1 FFD
 1B VHF-2 FFD
 1F Interphone
 1G Public address
 1H Ground crew call
 1J Voice recorder
 1M Selcal
 1N Transponder
 1P Voice
 1Q VHF-1 AFD
 1R VHF-2 AFD
 1S VHF-3 AFD
 1T Loudspeaker

Navigation

5D ADF/RMI 1
 5E VOR/RMI 2
 5G VOR/RMI 1
 5H VOR/RMI 2
 5K Standby compass
 5P DME-1
 5Q DME-2
 5U VHF/NAV-1 FFD
 5V VHF/NAV-2 FFD
 5W VHF/NAV-1 AFD
 5X VHF/NAV-2 AFD
 5Y VHF/NAV-3 AFD

Electronic displays

2H Advanced guidance and control system (AGCS)
 2J Electronic attitude director indicator (EADI)
 2K Multifunction display (MFD)
 2L Navigation control display unit (NCDU)

Sensor Systems

6A Weather radar
 6C Television

Flight Instruments

3A Indicated airspeed indicator
 3F Mach airspeed indicator
 3H Corrected barometer altitude indicator
 3J Radio altimeter
 3K Altitude alert system
 3L Vertical speed indicator
 3M Elapsed time indicator
 3N Clock
 3P Standby attitude reference indicator
 3R Flight director indicator (FDI)
 3S Course indicator (CI)
 3U Total air temperature indicator
 3V Approach progress display
 3W Instrument comparator display

Aircraft Subsystems

7A Hydraulics
 7B Electrical
 7C Fuel
 7D Air-conditioning
 7E Pressurization
 7F Propulsion
 7G Lights
 7H Oxygen
 7J Anti-ice
 7K Rain removal and defog
 7L APU
 7M Engine starting
 7P Fire/overheat/smoke detect
 7Q Doors

Flight Controls

4A Primary altitude controls
 4B Propulsion controls
 4C Thrust reverser controls
 4D Landing gear and brakes
 4E Flaps
 4F Speed brakes
 4G Trim
 4H Auto flight control
 4M Nose wheel steering
 4N Leading-edge devices

Crew

8A Vision
 8B Maps/charts/checklists/reference data
 8C Seats/seatbelts
 8D Emergency equipment
 8E Personal equipment

Table 3.—Control-Related Tasks

Control type	Number of tasks for this type	Example tasks	
		Task code	Task name/description
Toggle switch			
Two position	Two	1A 05	Set VHF-1 COMM TFR SW to LEFT.
		1A 06	Set VHF-1 COMM TFR SW to RIGHT.
Three-position	Three		(Similar to above)
Guarded	One task for each position		(Similar to above)
Rotary switch	One task for each switch position	1N 01	Set ATC FUNC SEL SW to OFF.
		1N 02	Set ATC FUNC SEL SW to STDBY.
		1N 03	Set ATC FUNC SEL SW to ON.
		1N 04	Set ATC FUNC SEL SW to LO SENS.
Thumbwheel	One task for each thumbwheel		(None used on the NASA 515)
Lever			
With detents	One task for each detent position	4D 01	Set LANDING GEAR LEVER to UP position.
		4D 02	Set LANDING GEAR LEVER to OFF position.
		4D 03	Set LANDING GEAR LEVER to DOWN position.
No detents	One task for each significant position	4B 05	Advance THRUST LVRS to VERTICAL position.
		4B 06	Advance THRUST LVRS to FULL THRUST position.
		4B 08	Retract THRUST LVRS to IDLE position.
Rotary knob	One	1Q 04	Adjust VHF-1L volume.
Handwheel	One	4M 01	Actuate NOSE GEAR STEERING WHEEL.
Pushbutton			
On/off	One	1N 07	Press ATC IDENT SW.
Push-on/	Two	2K 20	Select NAVAIDS OPTION.
push-off		2K 40	Deselect NAVAIDS OPTION.

controls, the number of tasks associated with each type, and examples. The control-related tasks were derived from references 18 and 23.

6.3.3 DISPLAY-RELATED TASKS

Every analog, digital, and discrete indicator shown on the FFD and AFD panels has one or more tasks associated with it. (See sec. 6.2 and Apps. Six and Seven, ref. 4.) Table 4 lists the various types of displays, the number of tasks associated with each type, and examples. The display-related tasks were derived from references 18, 23, and 24.

6.3.4 AUDITORY TASKS

Auditory tasks fall into two groups—monitoring of audible signals and monitoring of verbal communications. Table 5 lists the various types of auditory tasks and examples. The audible signal-monitoring tasks were derived from reference 18. The verbal auditory tasks were derived from the incoming radio communications specified in the scenarios (sec. 5) and from the internal cockpit requests and reports required by the checklists and other normal procedures found in reference 17.

6.3.5 VERBAL TASKS

Verbal tasks fall into two groups—internal cockpit callouts and communications via radio or intercom. Table 6 lists the types of verbal tasks and examples. The internal cockpit callouts and intercom verbal tasks were derived from the checklists and procedures in reference 17. The radio communications were derived from the scenarios. (See sec. 6.0.)

6.3.6 MISCELLANEOUS TASKS

Various tasks do not fit into the categories described previously, including adjusting seats and seatbelts, looking up reference data, retrieving checklists, checking fire extinguishers, etc. These tasks were derived from the checklists and procedures in reference 17.

6.4 TASK DURATION TIME DERIVATION

6.4.1 CONTROL- AND DISPLAY-RELATED TASKS

6.4.1.1 Ground Rules

Task duration times for all control- and display-related tasks were analytically calculated from geometric and human factors data. The following ground rules were observed for calculation of these task duration times:

1. Total task duration time was calculated from the sum of the time required to turn and look at the control or display (sec. 6.4.1.3) plus the time to reach to the control (sec. 6.4.1.4) plus the time to actuate the control or monitor the displayed information (sec. 6.4.1.5).

Table 4.—Display-Related Tasks

Display type	Number of tasks for this type	Examples	
		Task code	Task name/description
Discrete indicators			
On/off types	Two	7K 32	Monitor TANK NO. 1 FWD FUEL PUMP LO press LT ON.
		7K 33	Monitor TANK NO. 2 FWD FUEL PUMP LO press LT OFF.
Multicolored types	One task for each color	3V 08	Monitor GLIDE SLOPE ANNUN LT green
		3V 09	Monitor GLIDE SLOPE ANNUN LT amber.
		3V 10	Monitor GLIDE SLOPE ANNUN LT off.
Digital indicators	One	1A 01	Monitor VHF-1L FREQ INDIC.
Analog indicators	One task for each information element	7F 29	Monitor ENG NO. 1 EPR INDIC.
		7D 30	Monitor ENG NO. 1 EPR BUG.
CRT displays	One task for each information element	2J 01	Monitor ROLL ATT INDIC (EADI).
		2J 02	Monitor PITCH ATT INDIC.
		2J 03	Monitor ALTITUDE CALLOUT.
			o
			o
			o
Switch position	As required in checklists	7C 68	Check ENG NO. 2 FUEL HEAT SW OFF.

Table 5.—Auditory Tasks

Auditory task types	Examples	
	Task code	Task name/description
Monitor audible signals	1F 04 4D 31	Monitor COCKPIT CALL CHIME. Monitor LANDING GEAR NOT DOWN AND LOCKED WARNING HORN.
Monitor verbal communications		
Incoming radio messages	1P 02 1A 09	Monitor REQUEST. Monitor VHF-1 COMM AUDIO.
Cockpit callouts	1P 02 1P 04 1P 05	Monitor REQUEST. Monitor REPORT. Monitor RESPONSE.

Table 6.—Verbal Tasks

Verbal task type	Examples	
	Task code	Task name/description
Internal cockpit callouts	1P010005 1P030004 1P040028	Callout: "SET EPR AT XXX" Callout: "AFTER START CHECKLIST" Callout: "BEFORE TAKEOFF CHECKLIST COMPLETE"
Radio communications	1P030002 1P030019	Interphone comm: "STARTING NO. 2" Radio comm: "ATLANTA GROUND CONTROL, NASA 515 READY TO TAXI, OVER"

2. The origin from which the task was initiated was always the location of the eyes and hands at the completion of the previous task.
3. Time required to return to the rest position was not included.

6.4.1.2 Derivation of Reach Distances and Eye Angles

All distance and angular measurements used to calculate turn and reach times were taken from the output of Link 3 of Boeing program TX-105, a program developed for control cabin design evaluations. (See ref. 25.) This program and the option compute, among other things, the straight line hand movement distance between points and the angular eye movement between points. (See fig. 23 for an example of the TX-105 Link 3 output report.)

The basic input data required to execute TX-105 Link 3 are (1) the X-Y-Z location (buttock line-water line-station line) of the controls and displays (fig. 24) and (2) the sequence in which they are used.

The X-Y-Z locations of the controls and displays for both the FFD and AFD were derived in two ways:

1. From control location data listed unpublished data inputs for TX-105 Link 3 used in the 737 certification program
2. From measurements extrapolated from the control location data using scale drawings of the control panels (from refs. 18 and 23)

The sequence of use of the controls and displays was taken from references 17 and 26.

6.4.1.3 Turn Time

Time required for eye and head deflection was computed from the following equation:

$$T = \frac{\text{eye angle change (in deg)} \times 0.66 \text{ sec}}{90^\circ}$$

This formula was derived from time and motion data (ref. 27) in which a flat 0.66 sec is allotted for all turning movements up to 90°. The rational multiplier (actual deflection divided by 90) was imposed to make the factor more sensitive to the minimal body turns used in the cockpit. The eye angle change data used in this calculation were those derived from TX-105 data (described in sec. 6.4.1.2). These data are shown in the column Angular Change, Eye in figure 23.

6.4.1.4 Reach Time

Time to reach from one location to another was assessed according to table 7 (also from ref. 27). These data were plotted on a time versus distance plot, and a sequence of polynomial equations was derived to define the reach time for intermediate distances

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		MAY 06, 197E			737BASIC			PAGE 2	
MISSION SEGMENT	CRUISE	CONVENTIONAL 737 CLCKPIT			CREW MEMBER			CAPTAIN	
		CONDITION							
		CHANGE IN DISTANCE FROM			DISTANCE BETWEEN POINTS			ANGULAR CHANGE	
		EYE	LEFT	RIGHT	EYE	LEFT	RIGHT	EYE	TOTAL
		POINT	SHOULDER		POINT	HAND	HAND	LEFT	ANGLE
								HAND	EYE
TASK	ENGINE START LEVERS								
ENG NO. 1 EPR INDIC		6.2			40.7			72.3	32.5
CAPT RIGHT HAND RELAXED POS				3.3			32.9		136.0
ENG NO. 1 START LEVER CUT OFF		2.8		8.5	29.5		14.7	48.3	78.3
ENG NO. 1 START LEVER RUN POS		2.4		2.4	3.8		3.8	5.0	7.2
ENG NO. 1 EPR INDIC		5.2			26.5			44.1	32.5
ENG NO. 1 START LEVER RUN POS		5.2		.0	26.5		.0	44.1	74.8
ENG NO. 1 START LEVER CUT OFF		2.4		2.4	3.8		3.8	5.0	7.2
ENG NO. 1 EPR INDIC		2.8			29.5			48.3	32.5
TASK	ENG LVKHT SYS SETUP								
CAPT VIEW THRU NO. 1 WINDOW		1194.9			1139.9			32.5	.0
CAPT RIGHT HAND RELAXED POS				8.5			14.7		35.0
ENG NO. 1 OVRHT DETECT SW		1196.7		8.9	1236.4		16.3	97.9	97.8
ENG NO. 2 OVRHT DETECT SW		2.9		2.3	5.5		5.5	7.5	11.0
ENG OVRHT TEST SW		2.5		1.8	5.9		5.9	8.4	101.1
EXT TEST SW		4.3		3.4	6.3		6.3	11.0	98.4
EXT TEST LTS		.2			1.0			1.4	94.8
TASK	ENG NO. 1 FIRE								
CAPT VIEW THRU NO. 1 WINDOW		1191.9			1238.5			99.9	.0
CAPT RIGHT HAND RELAXED POS				12.7			22.8		51.8
CAPT ANNUN FNL		1207.0			1209.5			25.0	25.6
ENG NO. 1 FIRE WARNING SW		9.6		8.0	36.9		16.9	77.2	99.7
L. BOTTLE DISCHARGE LT		4.4			6.1			7.2	96.3
R. BOTTLE DISCHARGE LT		.7			1.1			1.3	96.2
FIREBELL CUTOFF SW		3.4		1.2	3.8		3.8	2.9	96.6
CAPT VIEW THRU NO. 1 WINDOW		1195.8			1235.9			96.8	.0
CAPT RIGHT HAND RELAXED POS				9.2			18.5		46.9
ENG NO. 1 FIRE WARNING SW		1197.4		8.0	1237.4		16.9	99.7	99.7
ENG NO. 1 FIRE WARNING SW		.0		.0	.0		.0	.0	99.7
ENG NO. 1 FIRE WARNING SW		.0		.0	.0		.0	.0	99.7
TASK	ENG NO. 2 FIRE								
CAPT VIEW THRU NO. 1 WINDOW		1197.4			1237.4			99.7	.0
CAPT RIGHT HAND RELAXED POS				8.0			16.9		44.3

Figure 23.—TX] 105 Link 3 Output—Example

Buttöck Water Station

line	line	line
A1 737BASIC	DN1009 R009.7	0201.9 0223.2 OFF SCHEDULE DESCENT LT
A1 737BASIC	DN1009 R009.7	0200.0 0218.6 LAND AUTO PRESS CNT
A1 737BASIC	DN1010 R011.6	0261.9 0223.2 MAN PRESS SYS ENG LT
A1 737BASIC	DN1010 R011.7	0259.8 0218.6 PRESS MODE SEL
A1 737BASIC	DN1011 R010.3	0201.0 0221.2 STANDBY PRESS RATE CNT
A1 737BASIC	DP1001 L011.0	0248.3 0209.5 CAPT ANNUN PNL
A1 737BASIC	DP1003 L000.0	0223.4 0230.0 ENG NO.1 OVRHT DETECT SW
A1 737BASIC	DP1004 L004.0	0223.4 0238.0 ENG OVRHT TEST SW
A1 737BASIC	DP1005 L003.0	0225.0 0237.0 ENG NO 1 FIRE WARNING SW
A1 737BASIC	DP1006 L002.7	0223.4 0235.5 WHEEL WELL FIRE WARNING LT
A1 737BASIC	DP1008 L000.0	0225.0 0237.0 APU FIRE WARNING SW
A1 737BASIC	DP1009 R001.5	0223.4 0236.0 ENG NO.2 OVRHT DETECT SW
A1 737BASIC	DP1010 R001.5	0223.4 0237.0 ENG NO.2 OVRHT LT
A1 737BASIC	DP1011 R002.7	0225.0 0237.0 ENG NO 2 FIRE WARNING SW
A1 737BASIC	DP1012 R002.5	0223.4 0235.5 L. BOTTLE DISCHARGE LT
A1 737BASIC	DP1013 R004.0	0223.4 0235.5 R. BOTTLE DISCHARGE LT
A1 737BASIC	DP1014 L001.2	0223.4 0236.0 APU BOTTLE DISCHARGE LT
A1 737BASIC	DP1020 L004.0	0223.4 0237.0 ENG NO. 1 OVRHT LT
A1 737BASIC	DP1021 L001.2	0223.4 0237.0 APU LET INLP LT
A1 737BASIC	DP1022 R000.5	0225.0 0235.5 FIREBELL CUTOFF SW
A1 737BASIC	DP1024 R004.2	0223.4 0238.0 EXT TEST LTS
A1 737BASIC	DP1024 R004.2	0223.4 0237.0 EXT TEST SW
A1 737BASIC	DP1100 R010.2	0248.3 0209.5 F.O. ANNUN PNL
A1 737BASIC	DP1002 R004.9	0209.7 0232.1 MON ENG 1 ANTI-ICE SW
A1 737BASIC	DP1003 R006.1	0205.7 0232.1 MON ENG 2 ANTI-ICE SW
A1 737BASIC	DP1017 R003.1	0206.8 0233.6 WING ANTI-ICE DUCT OVRHT LT
A1 737BASIC	DA1001 L003.6	0242.1 0199.0 ENG NO. 1 EPR INDIC
A1 737BASIC	DA1002 L008.3	0206.2 0236.6 STANDBY HYD. LO. PRESS LT
A1 737BASIC	DA1003 L010.1	0200.6 0233.1 YAW DAMPER ON OFF SW
A1 737BASIC	DA1004 L011.0	0200.0 0233.1 YAW DAMPER ANNUN LT
A1 737BASIC	DA1005 L000.0	0200.5 0220.0 APU OIL CIL TEMP LT
A1 737BASIC	DA1006 L000.0	0200.5 0220.0 APU HI OIL PRESS LT
A1 737BASIC	DA1007 L004.0	0200.5 0220.0 APU HI OIL TEMP LT
A1 737BASIC	DA1008 L003.0	0200.5 0220.0 APU OIL PRESS LT
A1 737BASIC	DA1009 L002.2	0259.9 0218.7 APU AC AMPS METER
A1 737BASIC	DA1010 L000.0	0207.1 0234.5 CIRCUIT BKR PANEL LTS BRIGHT CONT
A1 737BASIC	DA1011 L000.0	0206.3 0232.5 PANEL LTS BRIGHT CONT
A1 737BASIC	DA1012 L000.5	0204.3 0220.1 EQUIP COOLING LT
A1 737BASIC	DA1013 R000.5	0204.3 0228.1 EQUIP COOLING ON OFF SW
A1 737BASIC	DA1013 R000.5	0204.3 0228.1 MON EQUIP COOLING SW
A1 737BASIC	DA1014 L000.0	0203.5 0226.5 EMERG EXIT LTS SW
A1 737BASIC	DA1014 L000.0	0203.5 0226.5 MON EMERG EXIT LT SW POS
A1 737BASIC	DA1015 L000.0	0203.5 0226.5 EMERG EXIT LTS NOT ARMED LT
A1 737BASIC	DA1016 L000.7	0202.4 0224.0 NO SMOKING LT SW
A1 737BASIC	DA1016 L000.7	0202.4 0224.0 MON NO SMOKING LT SW
A1 737BASIC	DA1017 R000.0	0202.4 0224.0 FASTEN SEATBELTS LT SW
A1 737BASIC	DA1017 R000.7	0202.4 0224.0 MON SEAT BELT LT SW
A1 737BASIC	DA1016 L001.0	0201.5 0222.0 ATTENDENT CALL SW
A1 737BASIC	DA1019 R001.0	0201.5 0222.0 GND CALL SW
A1 737BASIC	DA1020 L000.9	0201.0 0221.0 CALL LT
A1 737BASIC	DA1021 L000.0	0200.4 0220.0 L RAIN REPELLANT SW
A1 737BASIC	DA1022 R000.6	0200.4 0220.0 R. RAIN REPELLANT SW
A1 737BASIC	DA1023 L008.3	0259.0 0217.0 LANDING LTS SW
A1 737BASIC	DA1023 L006.2	0237.6 0200.2 SPEED BRAKE ARMED LT
A1 737BASIC	DA1024 L005.5	0239.0 0212.0 L RUNWAY TURNOFF LT SW
A1 737BASIC	DA1025 L004.0	0239.0 0217.0 R RUNWAY TURNOFF LT SW
A1 737BASIC	DA1026 R000.0	0239.0 0217.0 POSITION LT SW

Figure 24.—TX-105 Input Data—Example

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Table 7.—Time Required for Controlled Reach

Distance, in.	Time, sec	Distance, in.	Time, sec
1	0.324	12	0.570
2	0.372	14	0.574
3	0.402	16	0.624
4	0.432	18	0.648
5	0.456	20	0.672
6	0.474	22	0.696
7	0.492	24	0.720
8	0.510	26	0.744
9	0.522	28	0.768
10	0.540	30	0.792

not shown in the table. The time allotments of this table are those for visually directed movements, which are stopped by muscular control and which terminate in a grasping or placing motion.

The reach distance data used in these computations were those derived from TX-105 data (described in sec. 6.4.1.2). These data are shown under the column headings Distance Between Points, Left Hand/Right Hand shown in figure 23.

6.4.1.5 Operation Time

Control operation times and visual monitoring times for the various types of controls and displays were derived from human factors data (refs. 28 and 29). The times used for the various items and their sources are listed in table 8.

Operation times for other control and monitor tasks that do not fit into the types listed in table 8 were either estimated, simulated, or calculated.

6.4.2 COMMUNICATION TASKS

The task duration times for all verbal communications were based on the stop-watch timed duration of the verbal delivery of the exact text of the communication.

6.4.3 OTHER TASKS

For tasks that did not fit into the previous categories, the task duration times were based on stop-watch timed simulations of the task. Examples of these other tasks are seat adjustment, approach chart retrieval and review, data lookup, fire extinguisher check, etc.

6.5 TASK SITUATIONS

An entity called "task situation" was created as a mechanism for reducing the number of tasks to be listed in the task catalog.

Many controls and displays are used by both the pilot and the copilot and are located between the two crewmembers. Actuation of a control on one of the center panels is a right-hand task for the pilot and a left-hand task for the copilot. Rather than creating a separate task number and description to make this right-hand/left-hand distinction, a situation number is used with a single task number/task name. This type of situation will have associated with it a unique channel activity allocation that distinguishes it from another situation. The situation number will direct the program to select the appropriate channel activity data associated with this task as it is applied to the operator performing the task. Task 3H-01, shown in figure 25, is an example of a task where this type of left-hand/right-hand situation is used.

The second use of the situation number is to account for different task duration times for a task. For example, the time required to adjust the throttles a small amount is quite different from the time required to apply full thrust on takeoff. The situation

Table 8.—Operating Time for Various Control and Display Types

Control/display type	Average operation time, sec	Reference
Pushbutton	1.04	28
Two-position toggle switch	1.11	28
Three-position toggle switch	1.35	28
Covered toggle switch	1.50	28
Single rotary switch	1.58	28
Rotary switch in an array	1.64	28
Single thumbwheel	1.95	28
Thumbwheel in an array	2.00	28
Hand lever, 5° to 10° movement	1.65	29
Hand lever, 10° to 20° movement	1.85	29
Hand lever, 20° to 40° movement	2.05	29
Hand lever, 40° to 60° movement	2.25	29
Rotary knob	1.69	29
Hand wheel	2.39	29
Discrete indicator	0.25	29
Analog indicator	2.00	29
Digital indicator	0.75	29

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TLA-1
TASK DATA CODING FORM

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TASK CODE NO.		TASK NAME AND/OR DESCRIPTION	DURATION TIME (SECONDS)	CHANNEL ACTIVITY - PERCENT OF DURATION TIME									
SUBSYS				EV	IV	LH	RH	LF	RF	COG	AUD	VBL	
3H	01	SET ALTIMETER SW TO ON	1 2.10		100	100				20			
			2 2.10		100		100			20			
4C	05	MON ENG NO. 2 REVER-	1 .55		100					20			
		SER UNLOCKED LT ON	2 .76		100					20			
10	04	ADJ VHF-11 VOLUME	1 1.58		50		100			20			
			2 2.15		50		100			20			
			3 1.58		50	100				20			
			4 2.15		50	100				20			

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Figure 25.—Example Tasks

number allows the analyst to use the same task number and title for both cases while the situation number directs the program to select the appropriate task duration time for the specific case. Task 4C-05, shown in figure 25, is an example of a task where this type of duration time situation is used.

Task 1Q-04, shown in figure 25, is an example of a single task where both types of situations are used.

6.6 CHANNEL ACTIVITY

In TLA-1, nine anatomical/physiological channels have been defined which the operator will use in performing tasks. These channels are: (1) internal vision, (2) external vision, (3) right hand, (4) left hand, (5) right foot, (6) left foot, (7) verbal, (8) auditory, and (9) cognition. Each task will require one or more of these channels to be used to perform the task.

For every task in TLA-1, an assessment was made as to which channel would be used in performing the task and what percentage of task duration time each channel would be used. For example, to turn the windshield wiper switch to ON, the pilot will use his eyes (internal vision) to look at the control plus his right hand to reach up and actuate the control and his cognition to think about what he is doing. Each of the first two channels will be involved 100% of the total time required to perform the task. However, he will use his cognitive channel only a small percentage of the time (estimated at 20%) since he can be aware of many things simultaneously.

The channel activity percentages assigned to each task and situation are estimates. In general, it was assumed that the appropriate channel was occupied 100% of the task duration time. The major exception to this was that a 20% cognitive channel activity was allocated for all tasks.

7.0 PHASE, EVENT, AND PROCEDURE DERIVATION

7.1 INTRODUCTION

Phases, events, and procedures are discussed in this section as a group because they are interrelated. Figure 26 shows the time-based relationship between these entities and their relationship to the scenarios and the tasks. As this figure shows, the mission (or flight) is a series of sequential flight phases (sec. 7.2). Each phase is a series of events (sec. 7.3.1) and of procedures (sec. 7.3.2). Each procedure is a sequence of tasks. The workload analysis worksheets (fig. 3) are used by the analyst to organize and define, these data prior to coding.

7.2 FLIGHT PHASES

Each flight phase is described by a code number, a descriptive name, a start time, and a listing of the events/procedures that compose the phase and when these events/procedures start. Section 8.2.1.2.2 shows how the phase data are coded. Section 8.2.1.2.1 shows how the sequence of phases and their respective start times are coded on the mission data coding form. All the phase data items are discussed in detail in the following sections. (See App. Nine, ref. 4, for a listing of the phases that were derived for the scenarios described in sec. 5.0.)

7.2.1 FLIGHT PHASE NAMES AND CODES

7.2.1.1 Normal Flight Phases

In TLA-1, the total mission (or flight) can be described by a sequence of normal flight phases. Table 9 lists 19 normal flight phase code numbers and titles from which the analyst can select those that pertain to the specific scenario being analyzed. Others can be added by the analyst if necessary. Each normal flight phase is given a four-character phase code number.¹ Figure 27 shows a typical sequence of normal flight phases that describe a scenario where no emergency or abnormality occurs.

7.2.1.2 Emergency Situations

The 19 flight phases listed in table 9 can be annotated to show that an emergency or abnormal event has occurred in or persisted through the various phases. This bookkeeping annotation is described in the following paragraphs and is used by the analyst to keep track of flight phases where emergencies or abnormal events have altered the normal procedures.

Table 10 lists all the emergency situations for the 737 as taken from reference 17. Each emergency is assigned a unique two-letter code that is used in the four-character flight phase code to show that an emergency event has occurred. This emergency code would be used in successive flight phase codes if the emergency situation persisted and/or if the procedures used during the successive flight phases were impacted by the earlier emergency.

¹ These phase names and code numbers have been borrowed from another Boeing computer program.

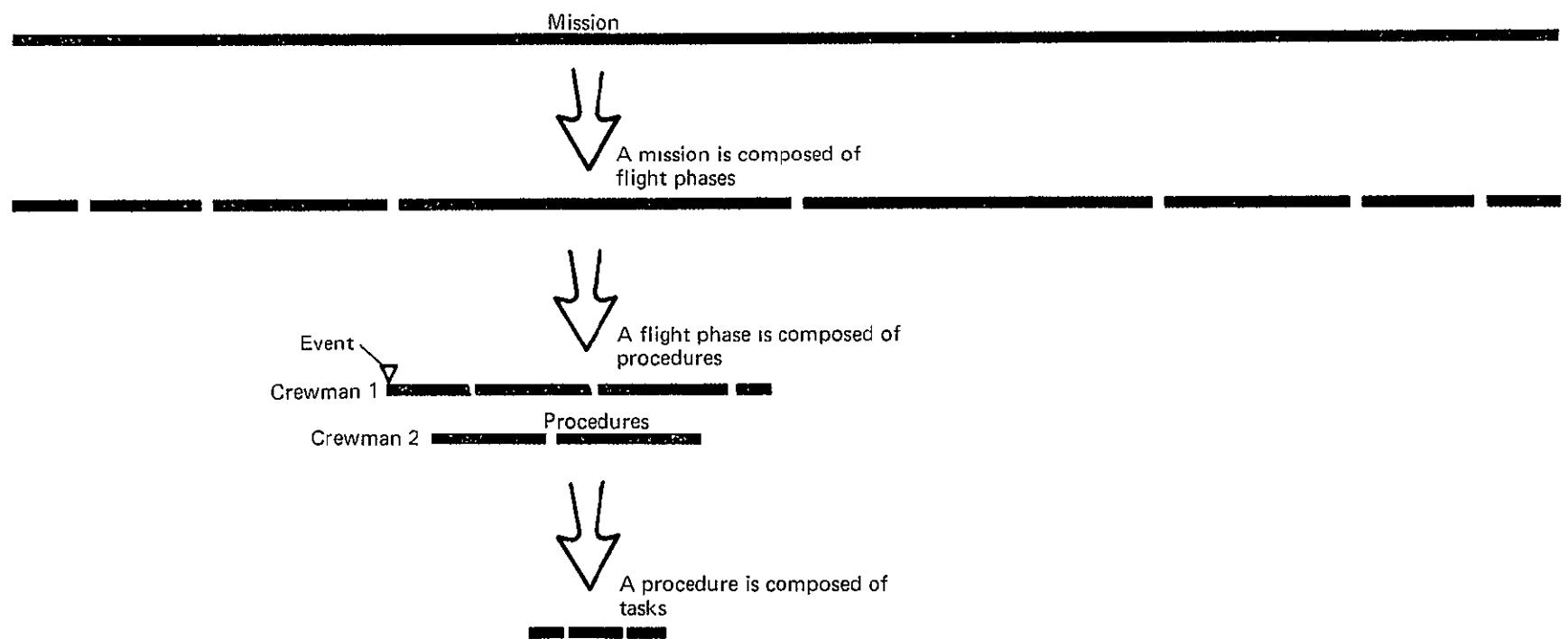


Figure 26.—Time-Based Relationship of Missions, Phases, Events, Procedures, and Tasks

Table 9.—Flight Phases

Phase code number	Phase name
0100	Prestart prep, FFD
0200	Prestart prep, AFD
0300	Start
0400	Taxi, before takeoff
0700	Takeoff, IFR
0900	Climb, noise abatement
1100	Cruise, normal airway
1200	Cruise, normal off airway
1300	Cruise, area navigation
1400	Descent, conventional procedures
1500	Descent, advanced procedures
1600	Approach/land, ILS procedural
1700	Approach/land, MLS procedural
1800	Approach/land, advanced procedures
1900	Approach/land, curved and segmented
2000	Park, visual
2100	Park, IFR (CAT III)
2200	Shutdown
2300	Taxi, after landing

Note: New flight phases can be added by the analyst as required.

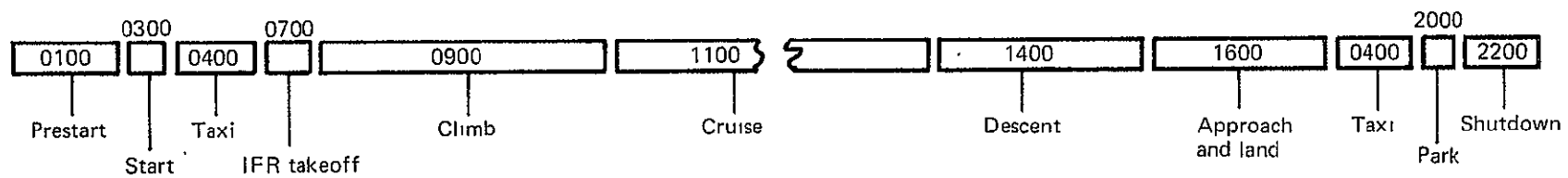


Figure 27.—Example of Typical Flight Phases Used To Define a Mission/Flight

Table 10—Emergency Situations

Name	Code
Engine fire, severe damage, or separation	XXEA
Engine overheat	XXEB
Electrical system smoke or fire	XXEC
Rapid depressurization	XXED
Emergency descent	XXEE
APU fire	XXEF
Wheel well fire	XXEG
Cockpit smoke	XXEH
Main cabin smoke	XXEI
Ditching	

Figure 28 shows a scenario where an engine overheat (code XXEB) occurred during the cruise phase (code 1100). The resulting flight phase code and description are

11EB Cruise–Engine Overheat

In this example, the overheat condition was taken care of and there was no subsequent impact on any other flight phase.

Figure 29 shows a scenario where a rapid depressurization (code XXED) occurred during normal airway cruise (code 1100). The resulting flight phase code and description are

11ED Normal Airway Cruise–Rapid Depressurization

In this example, the emergency had impact on the descent and the approach and land flight phases. Therefore, these flight phases are coded and described as

14ED Maximum Descent–Rapid Depressurization

16ED ILS Approach/Land–Rapid Depressurization

This coding system will not accommodate scenarios where multiple failures occur or persist through a flight phase. In such scenarios, the analyst is advised to stay with the normal flight phase coding or to adopt some other convention.

7.2.1.3 Abnormal Situations

Table 11 lists all the abnormal situations for the 737 as taken from reference 17. These abnormalities are coded and handled in a manner similar to the emergency situations described previously.

7.2.2 FLIGHT PHASE START TIME

The scenario will define the starting time of each flight phase relative to the total mission/flight start time. In some scenarios, the mission start time ($T = 0$) will start at the time the pilots enter the cockpit. The analyst may choose to start the mission at a specific time of day (for example, $T = 09:15:00$). Whichever time reference is used, the flight phase start times are always expressed as hours:minutes:seconds from the beginning time of the mission. See figure 30.

7.3 EVENTS AND PROCEDURES

As figure 26 shows, flight phases are made up of a series of events and procedures. Events are discussed in section 7.3.1 and procedures in section 7.3.2. Event and procedure start times are discussed in section 7.3.3. (See App. Eight, ref. 4, for a listing of the events and procedures that were derived for the scenarios described in sec. 5.0.)

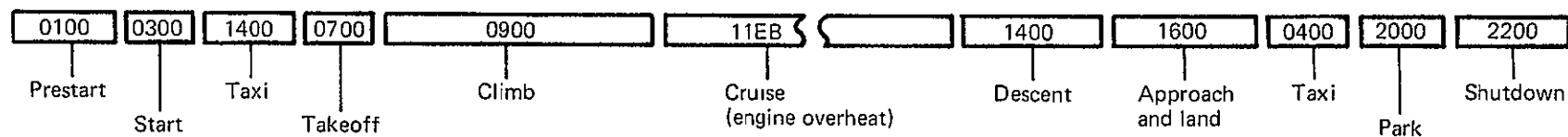
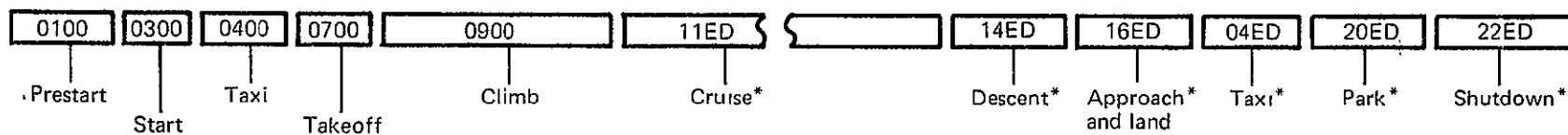


Figure 28.—Example of a Scenario That Includes an Emergency in a Phase That Does Not Impact Following Phases



*(Rapid depressurization)

Figure 29.—Example of a Scenario That Includes an Emergency in a Phase That Impacts Following Phases

Table 11.—Abnormal Situations

Name	Code
Engine shutdown in flight	XXAA
Engine start in flight	XXAB
One engine inoperative	XXAC
Reverser unlocked	XXAD
Low oil pressure	XXAE
Oil filter bypass	XXAF
Fuel heat valve failure	XXBA
Minimum fuel go-around	XXBB
Fuel filter icing	XXBC
Inadvertent fuel transfer	XXBD
Circuit breaker trip	XXCA
CSD low oil pressure	XXCB
CSD high oil temperature	XXCC
Standby power off	XXCD
Bus off	XXCE
Transfer bus off	XXCF
Equipment cooling off	XXCG
Loss of system A	XXDA
Loss of system B	XXDB
Loss of both systems A and B	XXDC
Gear not sealed	XXFA
Gear unsafe	XXFB
Loss of system A or B hydraulic brake pressure	XXFC
Hydraulic pump low pressure	XXFD
System B pump overheat	XXFE
One or both antiskids inoperative	XXFG
Auto brake inoperative	XXFF
Duct overheat	XXGA
Pack trip off	XXGB
Wing-body overheat	XXGC
Bleed trip off	XXGD
Auto fail	XXGE
Off-schedule descent	XXGD
Engine anti-ice valve failure	XXHA
Cockpit window failure	XXJA
Window overheat	XXJB
Runaway stabilizer	XXKA
Abnormal flight controls	XXKB
Jammed stabilizer	XXKC
Unsymmetrical or no leading-edge devices	XXKD
Unsymmetrical trailing-edge devices	XXKL
Flag-up landing	XXKM
Flight control low pressure	XXKN
Yaw Damper	XXKP
Stabilizer out of trim	XXKQ
Speed brakes do not arm	XXKR
Mach trim fail	XXKS

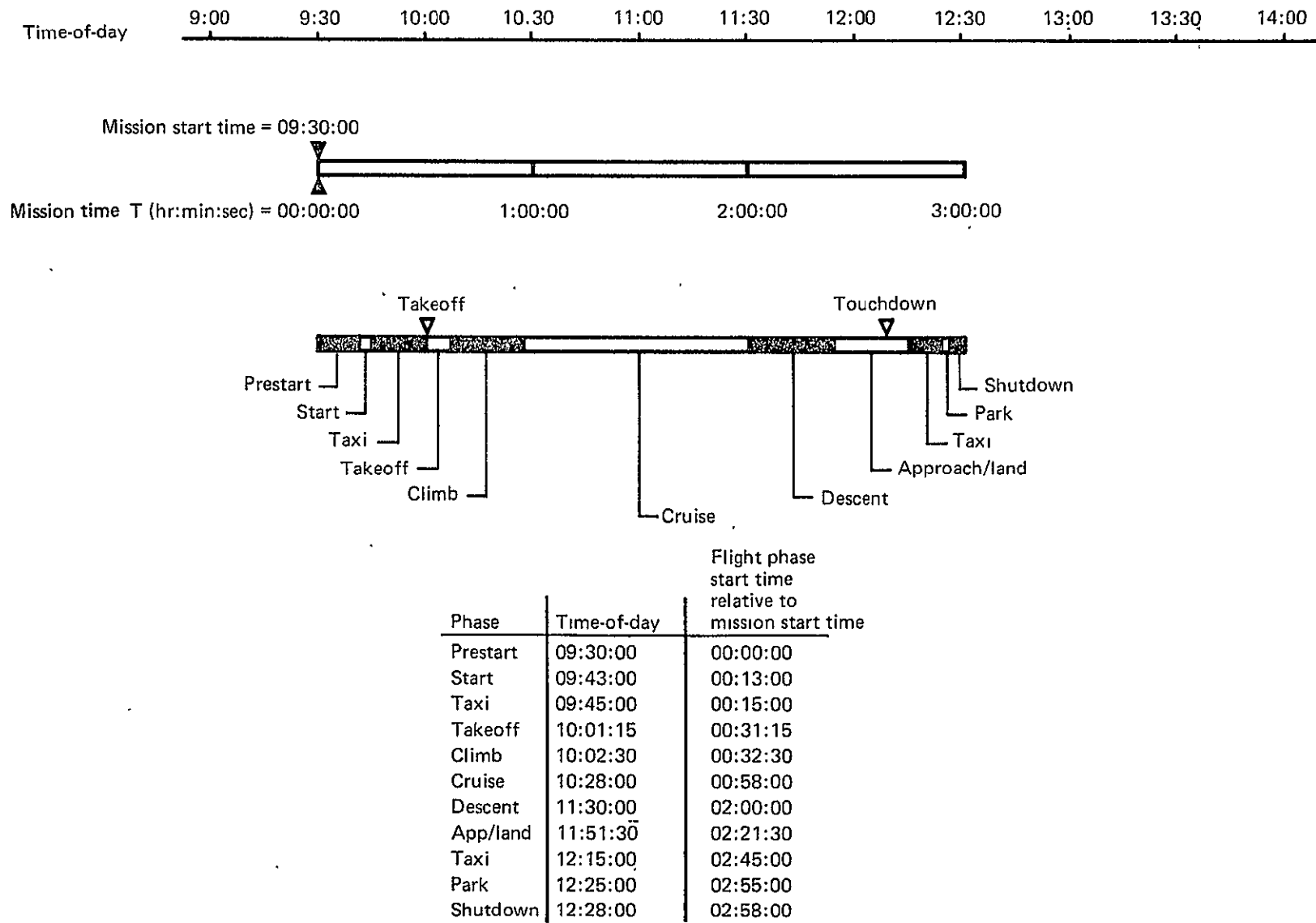


Figure 30.—Flight Phase Start Time

7.3.1 EVENTS

In TLA-1, an event has an event code number and a description. In general, an event is used as a mechanism to insert descriptions of significant milestones into the mission scenario report (sec 8.4.2.1) and the mission timeline plot (sec. 8.4.2.4). An event is distinguished from a procedure because an event does not have a task series associated with it. The following are examples of events:

<u>Event code number</u>	<u>Event description</u>
060002	Rotate
060003	Liftoff
060001	Receive takeoff clearance
090003	Cross Stubbs intersection
160011	Cross outer marker
160013	Cross inner marker
160014	Touchdown
09FE05	System B pump overheat anomaly

The first four characters in the six-character event code number are the code number of the flight phase in which the event occurred. The last two numbers are the sequence number of the event during the phase. This coding convention is purely arbitrary, and the analyst is free to adopt any one- to six-character coding convention that assigns a unique number to each event.

It is emphasized that the events are used only for inserting some reference information or landmarks into timelines and scenario reports to aid readers in interpreting this information. Events do not have any effect or impact on the statistical computations. In general, the events are derived from the scenarios.

7.3.2 PROCEDURES

In TLA-1, a procedure has a code number, a description, and a listing of the sequential order of tasks required to perform the procedure. Each task in a procedure is given a start time relative to the procedure start time, a task slide time, a crewmember assignment, and a task-situation number. Figure 31 is a typical event/procedure data coding form showing how these entities are coded, and the following sections describe the entities.

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TLA-1
EVENT/PROCEDURE DATA CODING FORM

EVENT/PROC CODE NO.		EVENT/PROCEDURE NAME OR DESCRIPTION		TASK CODE NO.		TASK START TIME		SLIDE (SEC)		CREW MEMBER		TASK CODE NO.		TASK START TIME		SLIDE (SEC)		CREW MEMBER			
						HR	MIN	SEC	-	+	1	2			HR	MIN	SEC	-	+	1	2
070004		CLEARED TO TAXI ONTO	1B	14				0				CP1	1B	15			0			CP1	
		RUNWAY 9L	1P070005					0				CP1	1P070006			3	6			CP1	
			1B	18				6				*2	1P070007			6			*1		
			1B	14				9				CP2	1B	15			9			CP2	
			1P070008					9				CP1	4D	52			13			P1	
			4B	03				14				P2	4M	01			14			P4	
			4B	03				24				P1	4D	28			27			P1	
			8A	04				10				P3									
070005		RECEIVE TAKEOFF	1B	18				0				P2	1P070009				0			*1	
		CLEARANCE	1B	14				3				P3	1B	15			3			P3	
			1P070010					3				P1									
070006		TAKEOFF ROLL	8A	02				0				P1	4A	64			0		2	P1	
			4B	05				0				P1	7F	29			3	1	2	P2	
			7F	34				3	1	2		P3	4B	06			5	1	1	P1	
			7F	27				8	1	2		CP2	7F	30			8	1	2	CP3	
			4B	07				10	2	2		CP1	3A	01			12	4	4	CP4	
			8A	04				4	2	2		P4	3A	01			20	4	4	P1	
			3A	09				20	2	2		CP3	1P070001				20			CP1	
			1P	12				20				P4	3A	03			25			CP4	
			1P070002					27				CP1	1P	11			27			P3	
070007		ROTATION, FLARE, AND	3A	06				0				CP4	1P070003				1			CP1	
		GEAR UP	1P	11				1				CP3	4A	24			2	7	3	P1	
			3A	01				4	2	2		CP2	4D	07			15			2CP2	
			4D	09				16				2CP3									
070008		SET HEADING BUGS TO	3S	11				0				P1	3S	12			5			P2	
		090 DEG AND COURSE	3S	11				5				CP1	3S	12			10			CP2	
		BUGS TO 105 DEG																			

Figure 31.—Event/Procedure Data Coding Form—Example

7.3.2.1 Procedure Code Number and Description

Each procedure is given a name or description and a procedure code number with up to six characters.

In the scenarios analyzed in this report, a procedure coding convention was adopted that is similar to the one used for events. (See sec. 7.3.1.) In this convention, the first four characters are the code number for the flight phase in which the procedure was first used. The last two numbers are the sequence number of the procedure during the phase. This is an arbitrary convention, and the analyst is free to assign any unique alphanumeric code using from one to six characters.

Almost all tasks that need to be performed can be grouped into procedures. The analyst is free to create meaningful names or descriptions for these procedures. In the detailing of the scenarios analyzed in this report, a repertoire of over 600 procedures has been defined. (See fig. 31.) The reader is referred to Appendix Eight (ref. 4) for a complete catalog of the procedures that have been developed to date.

For those tasks or task sequences in which a procedure name is not necessary or applicable, the analyst can leave the procedure name blank.

The procedures, in general, have been derived from reference 17 as required to accomplish the flights detailed in the various scenarios.

7.3.2.2 Procedure Task Data

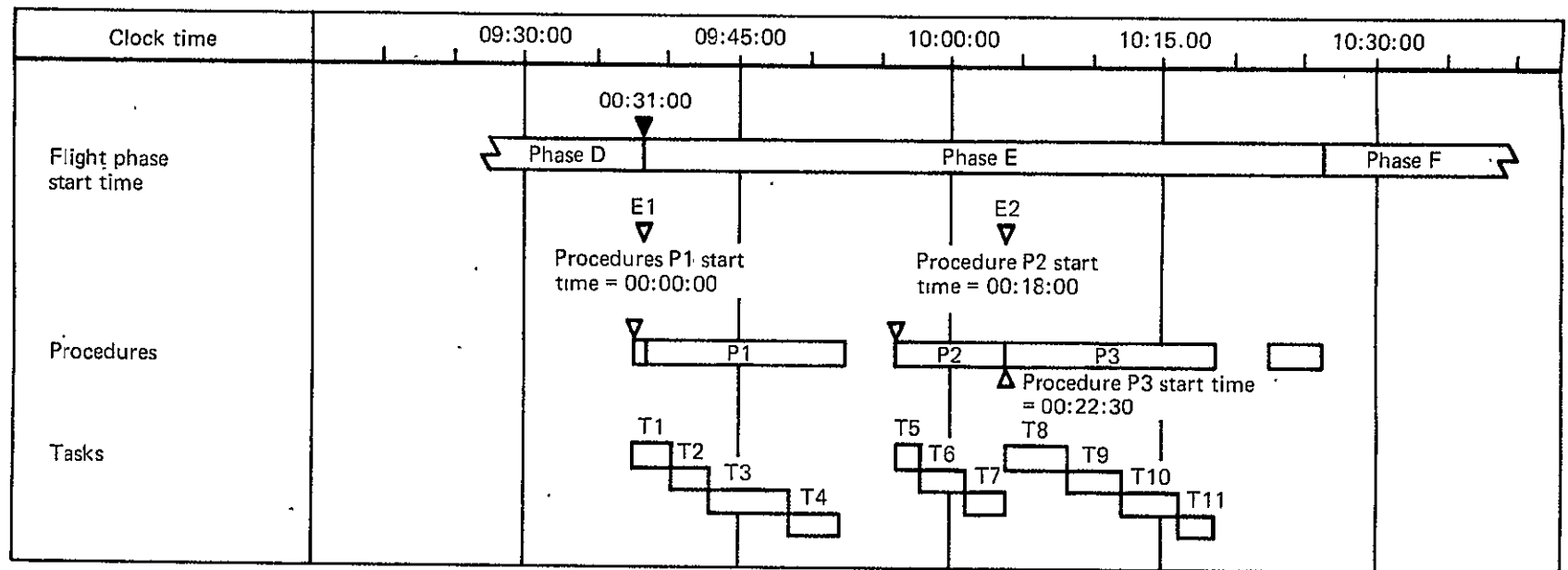
Each procedure is composed of one or more tasks. The analyst lists the task code number of each task to be performed.

The starting time for each task is specified relative to the procedure start time. (See fig. 32.) If a task can be started anytime within a time span, the analyst specifies a nominal task start time and then specifies the allowable time limits ahead and/or back in time. These limits are called the slide time limits. The TLA-1 program will attempt to move (slide) a task within these limitations, if there is a channel overload on a crewmember, in an attempt to relieve the overload. See section 8.3.3 for a detailed description of this process.

For each task in a procedure, the analyst specifies which crewmember performs the task. Each task in a procedure must have its situation number specified. (See sec. 6.5.)

7.3.3 EVENT AND PROCEDURE START TIMES

The start time for each event and procedure is specified relative to the phase start time. (See sec. 7.2.2.) As figure 32 shows, the start time of an event or procedure is expressed as hours:minutes:seconds after the start of the flight phase in which the procedure takes place.



Clock time	Phase	Phase start time	Procedure/event	Procedure/event start time	Task	Task start time
09:38:00	E	00:31:00 = 31 min after start of mission	E1	00:00:00		
			P1	00:00:00	T1 T2 T3 T4	00:00:00 ^a 00:02:00 00:04:00 00:11:00
09:56:00			P2	00:18:00 = 18 min after start of phase E	T5 T6 T7	00:00:00 ^b 00:01:30 00:04:15
10:00:30			E2	00:22:30		
			P3	00:22:30	T8 T10 T9 T11	00:00:00 00:07:00 00:04:30 00:12:30

^a2 min after start of P1

^b1 min 30 sec after start of P2

Figure 32.—Task Start Time

8.0 DATA PROCESSING

This section contains abbreviated descriptions of the TLA-1 program organization, data input, processing computations, and output data formats. This section is not to be used as directions for coding. Users are referred to the TLA-1 User's Guide (ref. 2) for complete instructions on how to use the TLA-1 model. For detailed information concerning the TLA-1 code, refer to the TLA-1 Programmer's Guide (ref. 3), which contains program flow charts, the program code, etc.

8.1 PROGRAM STRUCTURE

The program is divided into four modules. (See fig. 33.)

1. Control
2. Input (sec. 8.2)
3. Processor (sec. 8.3)
4. Report generation (sec. 8.4)

The control module processes all control cards and initiates the other three modules.

All mission data is input through the input module and output to an external permanent file.

The processor performs all calculations and functions and outputs the results to an external file. The input to the processor comes from the data stored by the input module.

The report generation module receives inputs of report requests and acts to produce the requested reports by using the data from the two external files created by the input module and the processor module. There may be as many as three sets of external files (different configurations of the same mission) input to create some reports.

8.2 INPUTS

Inputs to TLA-1 are from two sources: card and tape. The following sections describe the card types and formats and the tape inputs.

8.2.1 CARD INPUT

Card inputs to TLA-1 are of three classes:

1. Control specification (sec. 8.2.1.1)
2. Mission data (sec. 8.2.1.2)

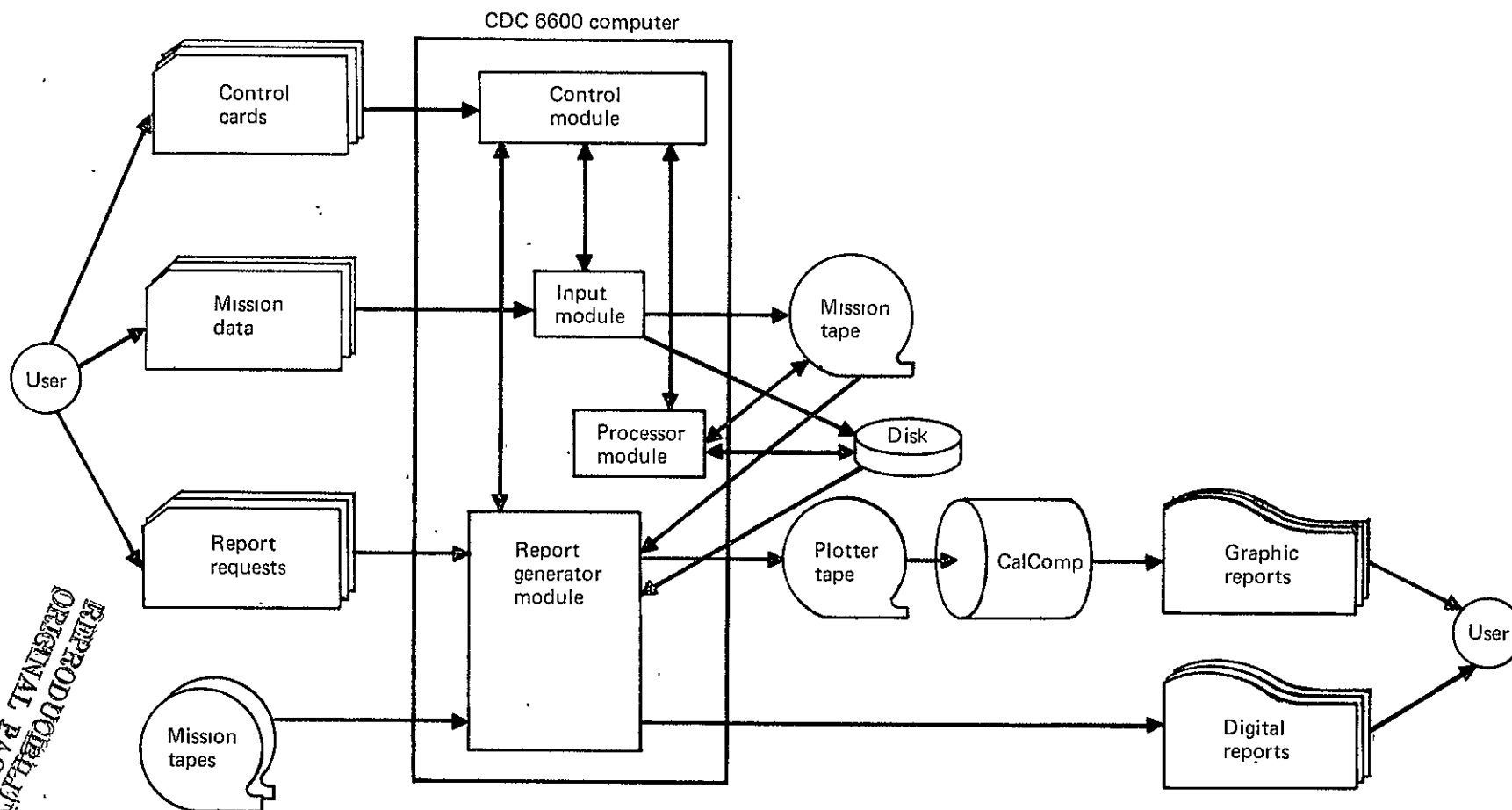


Figure 33.—TLA-1 System Diagram

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3. Report request specification (sec. 8.2.1.3)

The control specifications cause the functions to be executed. The mission data prescribe in detail a mission timeline. The report request specification causes reports to be generated.

8.2.1.1 Control Card

Control card input is used to initiate four functions: (1) input, (2) process, (3) output, and (4) terminate.

The input function causes the mission specification data to be input from cards, listed, and output to the mission tape.

The process function reads mission data from the mission tape, performs all functions specified in section 8.3, and outputs the processing results to a second file on the mission tape.

The output function inputs report request specification cards and one, two, or three mission tapes to create requested reports and plot tapes.

The terminate function causes all files to be closed and causes termination of program execution.

8.2.1.2 Mission Data Input

The mission data input is classified into five types: (1) mission specification, (2) phase specification, (3) event/procedure specification, (4) task specification, and (5) subsystem specification.

8.2.1.2.1 Mission Specification Input.—The mission specification will be given by three data types: (1) mission parameters, (2) mission profile, and (3) crewmember titles. Figure 34 is a sample of the mission data coding form that is used to specify the data types. Table 12 provides an explanation for the inputs.

8.2.1.2.2 Phase Specification Input.—As discussed in detail in section 7.2, the phase specification consists of phase identification, and even and procedure assignment. See figure 35.

The phase identification is a code of four characters and a name of up to 60 characters. The phase name can extend to 60 characters by continuing the name, 20 characters per card, for as many as three continuation cards. A card is a continuation of the phase if the first four columns are blank on succeeding cards.

Each event and procedure assigned to the phase is specified by an event or procedure number and the start time of the event or procedure relative to the phase start time. The start time is given in hours, minutes, and seconds.

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TLA-1
MISSION DATA CODING FORM

PROGRAM	PAGE	OF
PROGRAMMER	DATE	

MISSION PARAMETERS												
RUN DATE		MISSION TITLE				TIME INTV. (SEC)	STR TH HR MIN CO GIS	SLIDE INTVL (SEC)	SLIDE THSHD %	RUN CODE	CONF GURATION TITLE	
NOV 11, 1975		SCENARIO 1B - ILS WITH MALFUNCTIONS				5	00 00 00	1	80	2011454	515 - FFD	
MISSION PROFILE												
NO. 10												
PHASE CODE NO.	START TIME HR MIN SEC		PHASE CODE NO.	START TIME HR MIN SEC		PHASE CODE NO.	START TIME HR MIN SEC		PHASE CODE NO.	START TIME HR MIN SEC		
0100	0	0	0	0300	15	20	4700	34	35	111X	104	20
16EK	157	35	23EK	220	50	20EK	2	23	40			
CREWMEMBERS												
NO. 2												
CDR	NAME		CDR	NAME		CDR	NAME		CDR	NAME		
1	PILOT		2	COP-PILOT								

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Figure 34.—Mission Data Coding Form—Example

Table 12.—Mission Specification Input

Parameter	Description
RUN DATE	Date for the run, put on each report generated
MISSION TITLE	Title, put on each report generated
TIME INTVL	Time interval in seconds for the task processor. The entire mission is broken into intervals of this value. It is also the interval used for the statistics. This interval is the smallest interval for which channel workloading is considered. It is the total channel workload in this interval that is checked for exceeding of workload threshold.
STRT TM	Mission start time: The first two digits are hours, the second two digits are minutes.
SLIDE INTVL	Time step in seconds used for sliding a task if a channel threshold is exceeded
SLIDE THSHD	Channel threshold percentage criterion used to determine channel overload for task sliding
MISSION PROFILE	Number of phases specified for the mission
PHASE CODE NO.	A four-character phase designator
PHASE START TIME	Start time for the phase relative to mission start time: The first two digits are hours, the second two are minutes, and the last two are seconds.
NO. OF CREWMEMBERS	The number of crewmembers specified for the mission
CREWMEMBER CODE	A one- or two-character code to designate the crewmember
CREWMEMBER NAME	A 20-character label used on all report title blocks for a crewmember
RUN CODE	A two-digit integer to identify the run number
CONFIGURATION TITLE	Label used on all reports to designate the cockpit layout and manning

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PHASE DATA CODING FORM

PROGRAM	PAGE
PROGRAM NUMBER	OF
DATE	

PHASE CODE NO.		PHASE NAME		EVENT/PROC CODE NO.		EVENT/PROC START TIME		EVENT/PROC CODE NO.		EVENT/PROC START TIME		EVENT/PROC CODE NO.		EVENT/PROC START TIME		EVENT/PROC CODE NO.		EVENT/PROC START TIME		
						HR	MIN	SEC			HR	MIN	SEC			HR	MIN	SEC		
A400	TAXI - BEFORE TAKEOFF (FEED)	040001			0	040002			18	030007			100	040003			248			
		040004			454	040005			624	040006			721	030007			200			
		030007			300	030007			400	030007			500	030007			600			
		030007			700	040007			821	040008			1008							

Figure 35.—Phase Specification—Example

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8.2.1.2.3 Event/Procedure Specification Input.—As described in detail in sections 7.3.1 and 7.3.2, an event or procedure is specified by an identification code and a character name. A procedure is further specified by one or more associated task situations. Each task situation is specified by a task code, a start time, a slide time option, and the crewmember performing the task. Figure 36 is a sample coding form for the event/procedure specification.

The task code consists of two parts. The first part specifies the associated subsystem and is a two-digit alphanumeric code in the left of the task code field. The second part is an integer right-adjusted in the task code field.

The start time is relative to the procedure start time and is given in hours, minutes, and seconds.

The slide interval specifies the number of seconds the task may slide if a shift threshold is exceeded by a channel workload. (See sec. 8.3.3.) The first two columns specify the number of seconds that may be stepped backward; the second two columns specify the number of seconds that may be stepped forward.

The crewmember code is input for the crewmember or crewmembers responsible for the task.

If more than two task situations exist for a procedure, they may be added on succeeding cards, leaving the procedure number and procedure name description blank. In other words, succeeding cards are considered a continuation of the event/procedure specification if the first six columns are blank.

8.2.1.2.4 Task Specification Input.—As discussed in detail in section 5.0, a task is specified by a code number, a descriptive title, a set of situations, and the associated workload for each channel. Figure 37 is a sample of the task specification coding form.

The identification consists of a two-word code and a name of up to 60 characters. The first word of the identification code is two characters identifying the subsystem used in the task, and the second word is the integer that is the task number. The 60 characters are placed on consecutive cards, 20 per card, leaving the first eight columns blank on the continuation cards.

A situation within a task is identified by an integer (from 1 to 4) and the task-situation duration time in seconds. Situations are placed on successive cards, leaving the first eight columns blank on all cards except the first to denote a continuation.

The workload (percentage of channel use during task-situation duration) is specified for each of the following nine channels:

1. EV (external vision)
2. IV (internal vision)
3. LH (left hand)

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EVENT/PROCEDURE DATA CODING FORM

EVENT/PROC CODE NO.	EVENT/PROCEDURE NAME OR DESCRIPTION	TASK CODE NO.	TASK START TIME			SLIDE (SEC)		Crew MEMBER	Crew NUMBER	TASK CODE NO.	TASK START TIME			SLIDE (SEC)		Crew MEMBER	Crew NUMBER
			HR	MIN	SEC	-	+				HR	MIN	SEC	-	+		
070004	CLEARED TO TAXI ONTO RUNWAY 9L	1B 14			0					CP1 1B 15			0			CP1	
		1P070005			0					CP1 1P070006			3.6			CP1	
		1B 18			6					*2 1P070007			6			*1	
		1B 14			9					CP2 1B 15			9			CP2	
		1P070008			9					CP1 4D 52			13			P1	
		4B 03			14					P2 4M 01			14			P4	
		4B 03			24					P1 4D 28			27			P1	
		8A 04			10					P3							
070005	RECEIVE TAKEOFF CLEARANCE	1B 18			0					P2 1P070009			0			*1	
		1B 14			3					P3 1B 15			3			P3	
		1P070010			3					P1							
070006	TAKEOFF ROLL	8A 02			0					P1 4A 64			0		2	P1	
		4B 05			0					P1 7F 29			3	1	2	P2	
		7F 34			3	1	2	P3 4B 06			5	1	1	P1			
		7F 27			8	1	2	CP2 7F 30			8	1	2	CP3			
		4B 07			10	2	2	CP1 3A 01			12	4	4	CP4			
		8A 04			4	2	2	P4 3A 01			20	4	4	P1			
		3A 09			20	2	2	CP3 1P070001			20			CP1			
		1P 12			20			P4 3A 03			25			CP4			
		1P070002			27			CP1 1P 11			27			P3			
070007	ROTATION, FLARE, AND GEAR UP	3A 06			0			CP4 1P070003			1			CP1			
		1P 11			1			CP3 4A 24			2	7	3	P1			
		3A 01			4	2	2	CP2 4D 07			15			2CP2			
		4D 09			16			2CP3									
070008	SET HEADING BUGS TO 090 DEG AND COURSE BUGS TO 105 DEG	3S 11			0			P1 3S 12			5			P2			
		3S 11			5			CP1 3S 12			10			CP2			

Figure 36.—Event/Procedure Specification—Example

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TLA-1
TASK DATA CODING FORM

PROGRAM	PAGE	OF
PROGRAMMER	DATE	

TASK CODE NO.		SUBSY	TASK NAME AND/OR DESCRIPTION	1	2	DURATION TIME (SECONDS)	CHANNEL ACTIVITY - PERCENT OF DURATION TIME																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
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Figure 37.—Task Specification—Example

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4. RH (right hand)
5. LF (left foot)
6. RF (right foot)
7. COG (cognitive)
8. AUD (auditory)
9. VBL (verbal)

8.2.1.2.5 Subsystem Specification Input.—A subsystem is specified by a 2-character code and a 30-character name. In addition, eight columns are allotted for the ATA code number (ref. 30). Figure 38 is a sample coding form for preparation of this input.

8.2.1.3 Report Request Specifications

Fifteen different inputs are used to specify the reports to be generated. They are divided into three types:

1. Digital report request specifications (sec. 8.2.1.3.1)
2. Graphic report request specifications (sec. 8.2.1.3.2)
3. Class output specifications (sec. 8.2.1.3.3)

Samples of printer and plotter outputs are included in section 8.4.

A sample report request coding form is shown in figure 39. An explanation of required inputs or options is given in the section pertaining to the requested report.

A report is requested by a three-character code in the report field of the report request card. Table 13 is a cross reference for the report request codes. For each report, none, one, two, . . . , or five of the options in table 14 may be specified, or selected standard options may be requested by using SR1 through SR4.

8.2.1.3.1 Digital Report Request Specifications.—There are seven different line printer output reports: (1) mission scenario (MNS), (2) crewman workload profile (CWP), (3) crewman workload summary statistics (CWS), (4) task-channel activity (TCA), (5) subsystem activity (SSA), (6) subsystem activity summary (SAS), and (7) task list (TLS). Resulting reports are shown in section 8.4.

8.2.1.3.2 Graphic Report Request Specifications.—The following five plots will be available for request: (1) channel activity (CAS), (2) workload histogram (WLH), (3) workload summary (WLS), and (4) mission timeline (MTL). The resulting plots are shown in sec. 8.4.

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SUBSYSTEM CODING FORM

PROGRAM	PAGE	OF
PROGRAMMER	DATE	

CODE	SUBSYSTEM NAME	ATA CODE NO.
JA	VHF-1 (FFD)	23-21-02
JB	VHF-2 (FFD)	23-21-02
IF	INTERPHONE	23-42-03
IG	PUBLIC ADDRESS	23-31-00
IH	GROUND CREW CALL	23-43-00
IJ	VOICE RECORDER	23-71-02
IM	SELCAL	23-28-00
IN	TRANSPONDER	34-53-02
IP	VOICE	
IQ	VHF-1 (AFD)	23-21-02
IR	VHF-2 (AFD)	23-21-02
IS	VHF-3 (AFD)	23-21-02
IT	LOUDSPEAKER	23-21-02

Figure 38.—Subsystem Specification—Example

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TLA-1
REPORT REQUEST CODING FORM

PROGRAM	PAGE
PROGRAMMER	DATE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425	426	427	428	429	430	431	432	433	434	435	436	437	438	439	440	441	442	443	444	445	446	447	448	449	450	451	452	453	454	455	456	457	458	459	460	461	462	463	464	465	466	467	468	469	470	471	472	473	474	475	476	477	478	479	480	481	482	483	484	485	486	487	488	489	490	491	492	493	494	495	496	497	498	499	500	501	502	503	504	505	506	507	508	509	510	511	512	513	514	515	516	517	518	519	520	521	522	523	524	525	526	527	528	529	530	531	532	533	534	535	536	537	538	539	540	541	542	543	544	545	546	547	548	549	550	551	552	553	554	555	556	557	558	559	560	561	562	563	564	565	566	567	568	569	570	571	572	573	574	575	576	577	578	579	580	581	582	583	584	585	586	587	588	589	590	591	592	593	594	595	596	597	598	599	600	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625	626	627	628	629	630	631	632	633	634	635	636	637	638	639	640	641	642	643	644	645	646	647	648	649	650	651	652	653	654	655	656	657	658	659	660	661	662	663	664	665	666	667	668	669	670	671	672	673	674	675	676	677	678	679	680	681	682	683	684	685	686	687	688	689	690	691	692	693	694	695	696	697	698	699	700	701	702	703	704	705	706	707	708	709	710	711	712	713	714	715	716	717	718	719	720	721	722	723	724	725	726	727	728	729	730	731	732	733	734	735	736	737	738	739	740	741	742	743	744	745	746	747	748	749	750	751	752	753	754	755	756	757	758	759	760	761	762	763	764	765	766	767	768	769	770	771	772	773	774	775	776	777	778	779	780	781	782	783	784	785	786	787	788	789	790	791	792	793	794	795	796	797	798	799	800	801	802	803	804	805	806	807	808	809	810	811	812	813	814	815	816	817	818	819	820	821	822	823	824	825	826	827	828	829	830	831	832	833	834	835	836	837	838	839	840	841	842	843	844	845	846	847	848	849	850	851	852	853	854	855	856	857	858	859	860	861	862	863	864	865	866	867	868	869	870	871	872	873	874	875	876	877	878	879	880	881	882	883	884	885	886	887	888	889	890	891	892	893	894	895	896	897	898	899	900	901	902	903	904	905	906	907	908	909	910	911	912	913	914	915	916	917	918	919	920	921	922	923	924	925	926	927	928	929	930	931	932	933	934	935	936	937	938	939	940	941	942	943	944	945	946	947	948	949	950	951	952	953	954	955	956	957	958	959	960	961	962	963	964	965	966	967	968	969	970	971	972	973	974	975	976	977	978	979	980	981	982	983	984	985	986	987	988	989	990	991	992	993	994	995	996	997	998	999	1000	1001	1002	1003	1004	1005	1006	1007	1008	1009	1010	1011	1012	1013	1014	1015	1016	1017	1018	1019	1020	1021	1022	1023	1024	1025	1026	1027	1028	1029	1030	1031	1032	1033	1034	1035	1036	1037	1038	1039	1040	1041	1042	1043	1044	1045	1046	1047	1048	1049	1050	1051	1052	1053	1054	1055	1056	1057	1058	1059	1060	1061	1062	1063	1064	1065	1066	1067	1068	1069	1070	1071	1072	1073	1074	1075	1076	1077	1078	1079	1080	1081	1082	1083	1084	1085	1086	1087	1088	1089	1090	1091	1092	1093	1094	1095	1096	1097	1098	1099	1100	1101	1102
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Table 13.—Report Request Codes

Report/plot code	Report
MNS	Mission scenario
CWP	Crewman workload profile
CWS	Crewman workload summary statistics
TCA	Task channel activity
SSA	Subsystem activity
SAS	Subsystem activity summary
TLS	Task list
CAS	Channel activity
WLH	Workload histogram
WLS	Workload summary
MTL	Mission timeline
SR1	Standard report set 1
SR2	Standard report set 2
SR3	Standard report set 3
SR4	Standard report set 4

Table 14.—Report Request Options

Option	Description																												
Crewmember (CRWMBR)	A two-character code that must be one of those input on the crewmember card of the mission data cards: If a report is to be generated for each crewmember, the two characters will be "****" (double astrisk).																												
Shift option (SHIFTED/UNSHIFTED)	A one-character code specifying the shift option as follows: S, report with task shifting U, report with no task shifting *, a report with task shifting and a report with no task shifting																												
Phase	A four-character code that must be one of the codes on the mission profile card in the mission data cards: If the four-character code is all asterisks ("****"), then a report is created for every phase.																												
Report threshold (RPT THSD)	An integer specifying the percent workload governing the output of the report: It is an exclusion parameter that causes only workloads exceeding its value to be considered for the report.																												
Subsystem (SUB SYST)	A two-character code that identifies the subsystem to be considered for certain outputs: This must be one of the subsystems in the subsystem input.																												
Average + 1 or average (AVE/AVE + 1 SIG)	A three-character code that controls bar plots and is used to specify the average plus 1σ bars ("A+1") or the average-only bars ("AVE").																												
Channel or channel group (CHNL/TOT)	A three-character field used to specify a specific channel, channel group, or average channel. The following are valid codes. Channels <table><tr><td>EV</td><td>External vision</td><td>RF</td><td>Right foot</td></tr><tr><td>IV</td><td>Internal vision</td><td>COG</td><td>Cognitive</td></tr><tr><td>LH</td><td>Left hand</td><td>AUD</td><td>Auditory</td></tr><tr><td>RH</td><td>Right hand</td><td>VBL</td><td>Verbal</td></tr><tr><td>LF</td><td>Left foot</td><td></td><td></td></tr></table> Channel Groups <table><tr><td>VIS</td><td>Visual</td><td>COG</td><td>Cognitive</td></tr><tr><td>MOT</td><td>Motor</td><td>COM</td><td>Communicative</td></tr></table> Average Channel AVC Weighted average channel	EV	External vision	RF	Right foot	IV	Internal vision	COG	Cognitive	LH	Left hand	AUD	Auditory	RH	Right hand	VBL	Verbal	LF	Left foot			VIS	Visual	COG	Cognitive	MOT	Motor	COM	Communicative
EV	External vision	RF	Right foot																										
IV	Internal vision	COG	Cognitive																										
LH	Left hand	AUD	Auditory																										
RH	Right hand	VBL	Verbal																										
LF	Left foot																												
VIS	Visual	COG	Cognitive																										
MOT	Motor	COM	Communicative																										
COMPARISONS	A set of three fields that identifies up to three sets of runs-phases to be compared in the comparison bar charts																												
PLOTTER TYPE	A six-character code that identifies the type of plotting machine to be used: <table><tr><td>CALCMP</td><td>CALCOMP PLOTTER</td></tr><tr><td>SC4020</td><td>SC4020 PLOTTER</td></tr></table>	CALCMP	CALCOMP PLOTTER	SC4020	SC4020 PLOTTER																								
CALCMP	CALCOMP PLOTTER																												
SC4020	SC4020 PLOTTER																												

8.2.1.3.3 Class Output Specifications.—Four classes of output cause sets of reports to be generated as requested by the SR1, SR2, SR3, or SR4 request codes. Table 15 specifies the reports for each class.

8.2.2 MISSION DATA TAPE INPUT

This tape consists of two files: one for the mission data card input and the other for the processor module output, which will be used to generate the reports. The use of tape inputs is discussed in detail in the User's Guide (ref. 2).

8.3 PROCESSING FUNCTIONS

This section describes the following functions to be performed to produce data for the output reports: (1) task processing, (2) phase statistics, (3) task-situation time shift, (4) task-channel activity calculations, and (5) subsystem activity calculations.

8.3.1 TASK PROCESSING

The task processing function uses the task-situation channel workloads and performs the following:

1. Calculates the time intervals spanned by the task situation
2. Calculates the workload contributions to study-time intervals
3. Updates the study-time interval workload sums
4. Calculates the channel group workload
5. Calculates the weighted average channel workload

8.3.1.1 Time Intervals Spanned by a Task

The equations giving the time intervals spanned by a task are presented in this section.

If a task starts at time t_{TS} (fig. 40) and is of duration t_T , the first interval within a phase in which the task contributes to workload is T_{ISF} to $(T_{ISF} + \Delta t)$. T_{ISF} is given by

$$T_{ISF} = [t_{TS}/\Delta t] \Delta t$$

where

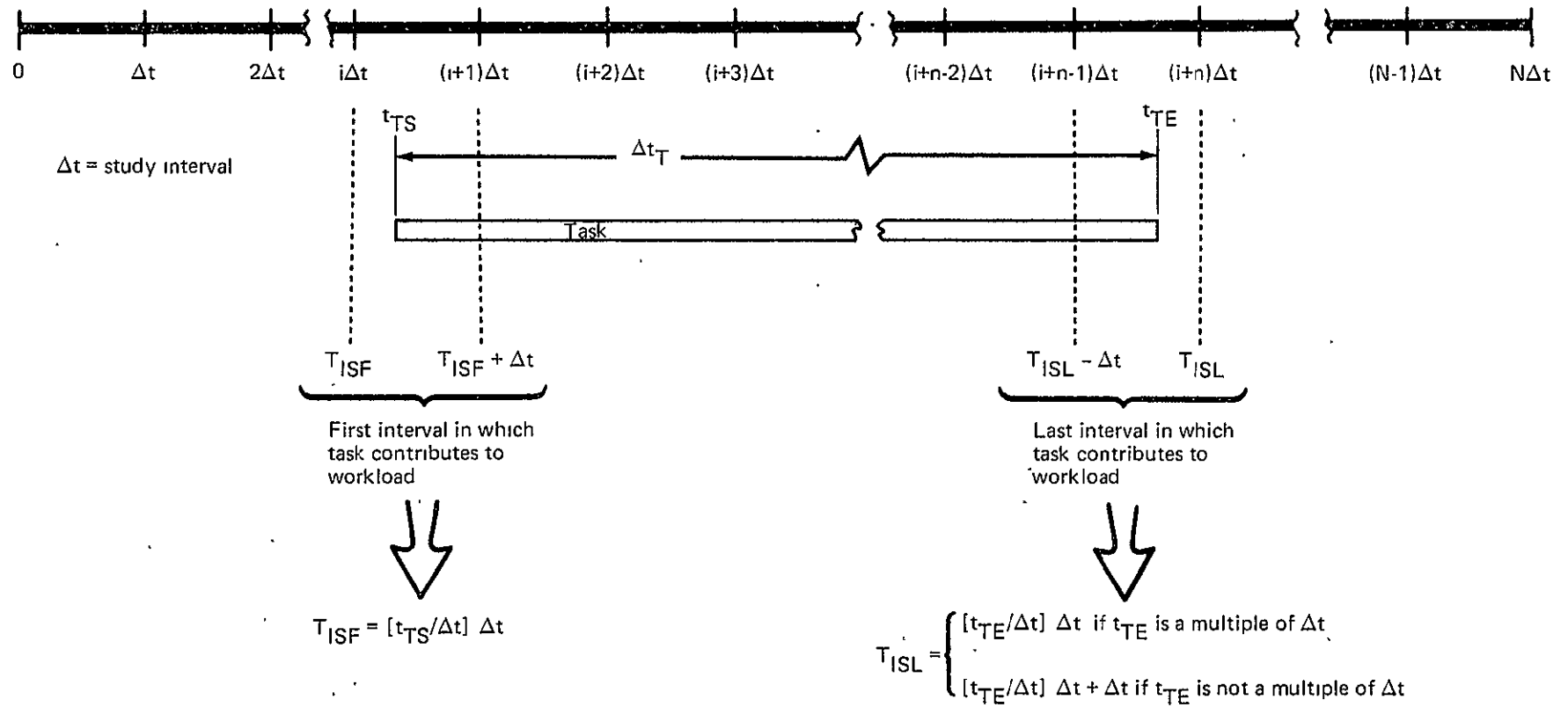
[] indicates the greatest integer less than or equal to the expression in the bracket

Δt is the study-time interval

Table 15.—Standard Report Requests

Standard report request number	Description
1 (SR1)	<p>The following reports are for all crewmembers, are nonshifted, and are for all phases with an option for subsystem and task channel activity reports.</p> <p>Crewman workload profile report Crewman workload summary statistics report Mission scenario report</p> <p>The following two types of reports are selected with the subsystem option and with a threshold of 75%.</p> <p>Subsystem activity reports Task channel activity report</p>
2 (SR2)	This report set is the same as SR1 but with shifting.
3 (SR3)	<p>This report set is the same as SR1 plus the following plots:</p> <p>Workload summary plot with average plus 1σ and standard configuration Channel activity plots with average plus 1σ Workload histograms with standard configuration and average channel Mission timeline plot</p>
4 (SR4)	<p>This report set is the same as SR3 but with shifting.</p> <p>When comparative data plots are to be output (workload summary plot, workload histogram), it is necessary to load the mission tapes (two maximum) of the runs that will be compared with the data from the run being processed.</p> <p>Mission tape input: The mission tape will consist of two files. The first will be the mission data card input and the second will be a file of the process module output that will be used to generate the reports.</p>

Note: These calculations are performed for each task.



where $[] = \text{greatest integer } \leq \text{to value in brackets}$

Figure 40.—Time Intervals Spanned by a Task

The last interval in which the task contributes is $(T_{ISL} - \Delta t)$ to T_{ISL} , and

$$T_{ISL} = \begin{cases} [t_{TE}/\Delta t] \Delta t, & \text{if } t_{TE} \text{ is a multiple of } \Delta t \\ [t_{TE}/\Delta t] \Delta t + \Delta t, & \text{if } t_{TE} \text{ is not a multiple of } \Delta t \end{cases}$$

The square brackets $[]$ indicate the greatest integer less than or equal to the value in the brackets.

The task end time t_{TE} is given by

$$t_{TE} = t_{TS} + \Delta t_T$$

Examples of this computation are shown in figures 41 and 42.

8.3.1.2 Channel Workload for Study-Time Interval

If a study-time interval is from t_{IS} to t_{IE} (fig. 43) the associated percent channel workload W_A is calculated from

$$W_A = \frac{[\min(t_{IE}, t_{TE}) - \max(t_{IS}, t_{TS})] W_{CT}}{\Delta t}$$

where

t_{IS} = interval start time

t_{IE} = interval end time

Δt = time interval between t_{IS} and t_{IE}

t_{TS} = task start time

t_{TE} = task end time

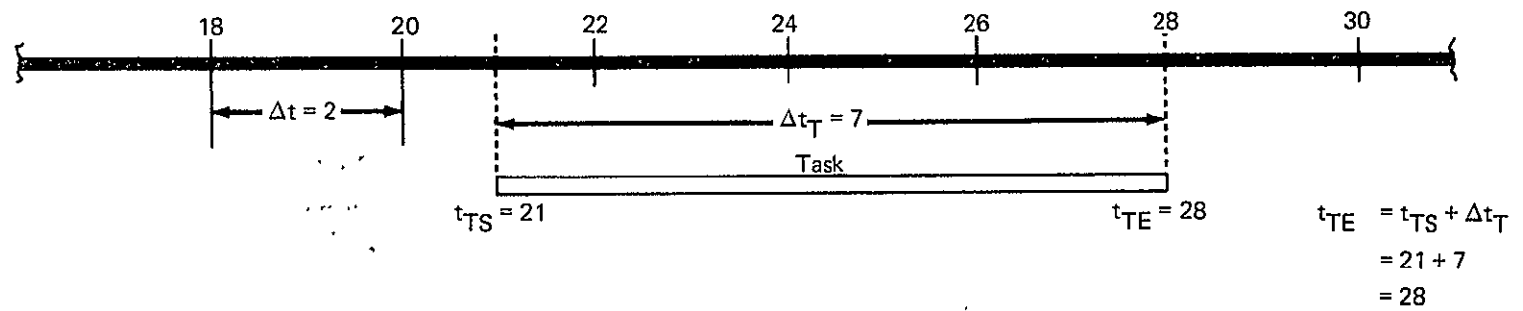
W_{CT} = percent channel workload for the task situation

Figure 44 shows an example of this computation.

8.3.1.3 Update of Study-Time Interval Workload Adders

A sum exists for each channel, channel group, and the weighted average channel for every study-time interval.

Using the equation in section 8.3.1.2, the contribution of each of the sums is calculated and accumulated into the appropriate study-time interval sums.



$$\begin{aligned}
 T_{ISF} &= [t_{TS}/\Delta t] \Delta t \\
 &= \frac{21}{2} 2 \\
 &= [10.5] 2 \\
 &= (10) (2) \\
 T_{ISF} &= 20
 \end{aligned}$$

$$\begin{aligned}
 T_{ISL} &= [t_{TE}/\Delta t] \Delta t \\
 &= \frac{28}{2} 2 \\
 &= (14) (2) \\
 T_{ISL} &= 28
 \end{aligned}$$

Figure 41.—Sample Calculation of Time Intervals Spanned by a Task—Example A

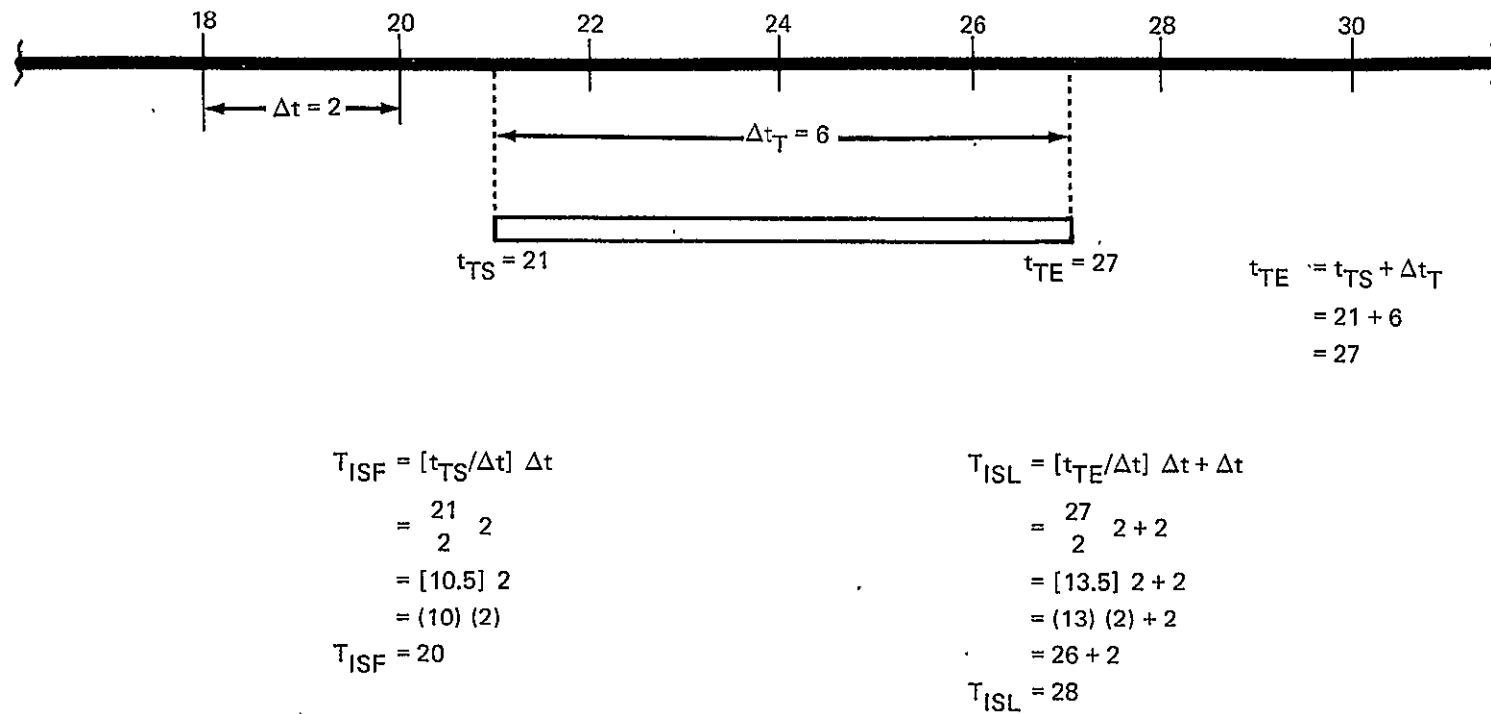
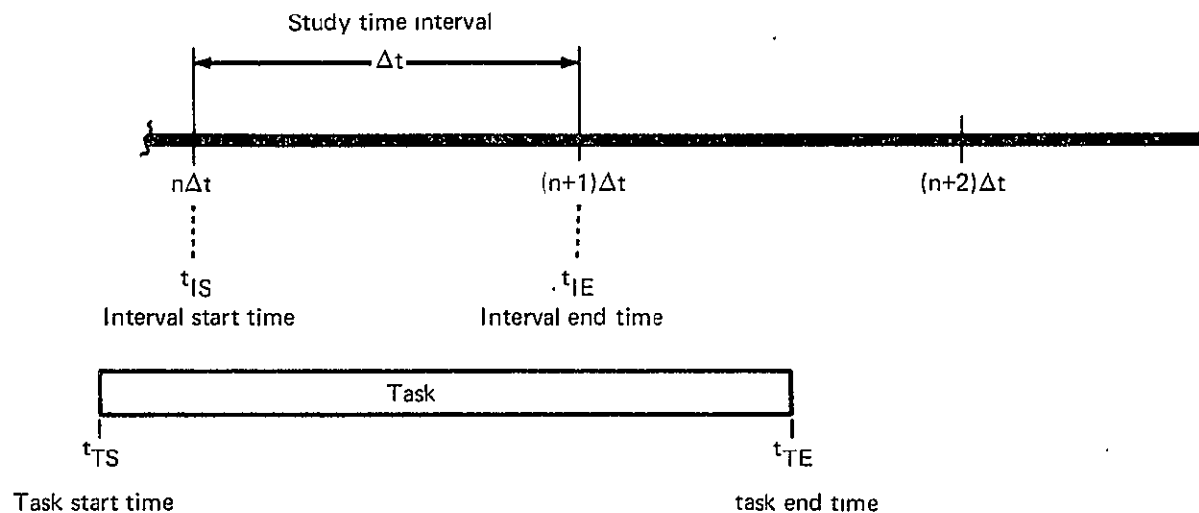


Figure 42.—Sample Calculation of Time Intervals Spanned by a Task—Example B



$$\text{Workload for channel N during study time interval} = W_{A,N} = \frac{[\min(t_{IE}, t_{TE}) - \max(t_{IS}, t_{TS})]}{\Delta t} W_{CT,N}$$

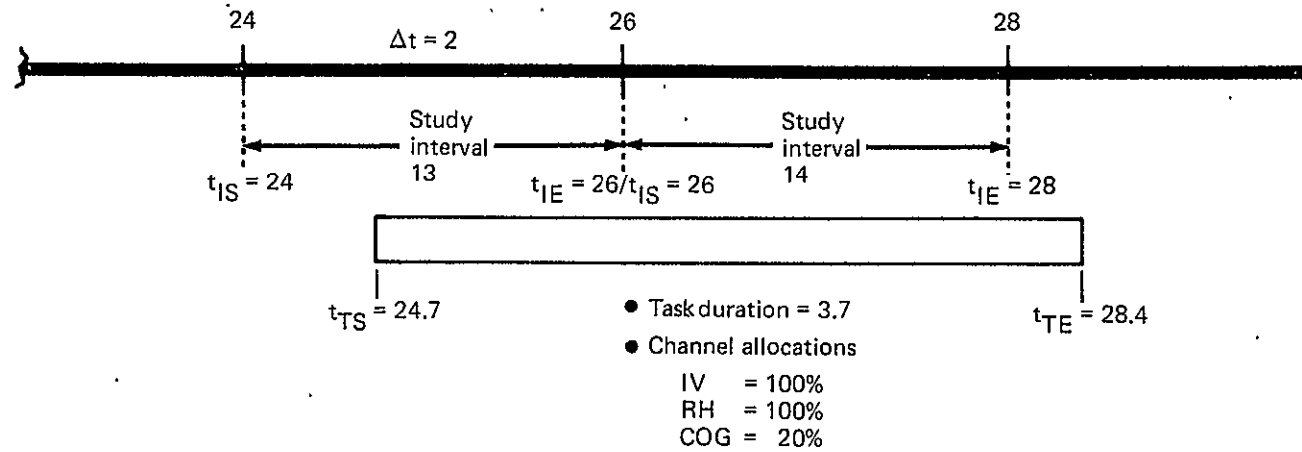
where $W_{CT,N}$ = the allocated channel N activity

Note:

This calculation is performed for each channel, channel group, and weighted average for each study time interval for every task that occurs within the study time interval.

The results of this computation for each channel, channel group, and weighted average are accumulated into the appropriate study time interval sums.

Figure 43.—Channel Workload for Study-Time Interval Calculation



Workload for IV channel
during study interval 13

$$\begin{aligned}
 W_{A,IV} &= \frac{[\min(t_{IE}, t_{TE}) - \max(t_{IS}, t_{TS})]}{\Delta t} W_{CT,IV} \\
 &= \frac{[\min(26, 28.4) - \max(24, 24.7)] (100)}{2} \\
 &= \frac{(26 - 24.7) (100)}{2} \\
 &= 26\%
 \end{aligned}$$

Workload for IV channel
during study interval 14

$$\begin{aligned}
 &= \frac{[\min(28, 28.4) - \max(26, 24.7)] (100)}{2} \\
 &= \frac{(28 - 26) (100)}{2} \\
 &= 100\%
 \end{aligned}$$

Figure 44.—Example of the Channel Workload for Study-Time Interval Calculation

8.3.1.4 Channel Group Workload Calculation

For each task situation, the visual, motor, communication, and cognitive channel group workloads are calculated from the following equations:

$$W_{G,VIS} = W_{C,IV} + W_{C,EV}$$

$$W_{G,MOT} = \frac{(W_{C,LH} + W_{C,RH} + W_{C,LF} + W_{C,RF})}{4}$$

$$W_{G,COM} = W_{C,VBL} + W_{C,AUD}$$

$$W_{G,COG} = W_{C,COG}$$

where

$W_{C,IV}$ = internal vision workload

$W_{C,EV}$ = external vision workload

$W_{C,LH}$ = left-hand workload

$W_{C,RH}$ = right-hand workload

$W_{C,LF}$ = left-foot workload

$W_{C,RF}$ = right-foot workload

$W_{C,VBL}$ = verbal workload

$W_{C,AUD}$ = auditory workload

$W_{C,COG}$ = cognitive workload

8.3.1.5 Weighted Average Channel Calculation

The weighted average channel \bar{W} is the average of the channel group workloads.

$$\bar{W} = \frac{(W_{G,VIS} + W_{G,MOT} + W_{G,COM} + W_{G,COG})}{4}$$

8.3.2 PHASE STATISTICS

The following statistics are calculated across all time intervals in a phase for each channel, each channel group, and the weighted average channel:

1. Workload sum S_W

2. Sum of the squares of workload S_{W2}
3. Mean workload \bar{W}
4. Workload variance σ^2
5. Standard deviation of the workload σ

The equations for the five calculations are:

$$S_W = \sum_{i=1}^{N_I} W_i$$

$$S_{W2} = \sum_{i=1}^{N_I} W_i^2$$

$$\bar{W} = S_W/N_I$$

$$\sigma^2 = S_{W2}/(N_I - 1) - \bar{W}^2$$

$$\sigma = \sqrt{\sigma^2}$$

where

N_I = the number of time intervals

W_i = the workload for time interval i

8.3.3 TASK-SITUATION TIME SHIFT FUNCTION

After all task processing has been completed, the shift function will be performed if the option is specified. The shift function checks each time interval in turn to determine if any channel workload exceeds a specified shift threshold criterion. If a channel workload exceeds the shift threshold, an attempt is made to slide start times of those task situations contributing to the workload excess. Only those task situations that have the slide option specified are used to attempt reduction of the excess workload.

Priority for shifting to be done is given to those channel workloads with the highest values, which will be the first for which an attempt is made to reduce workload. Further, those task situations that make the highest contribution to the workloads exceeded will be the ones for which the slide is first attempted, if a slide is permissible.

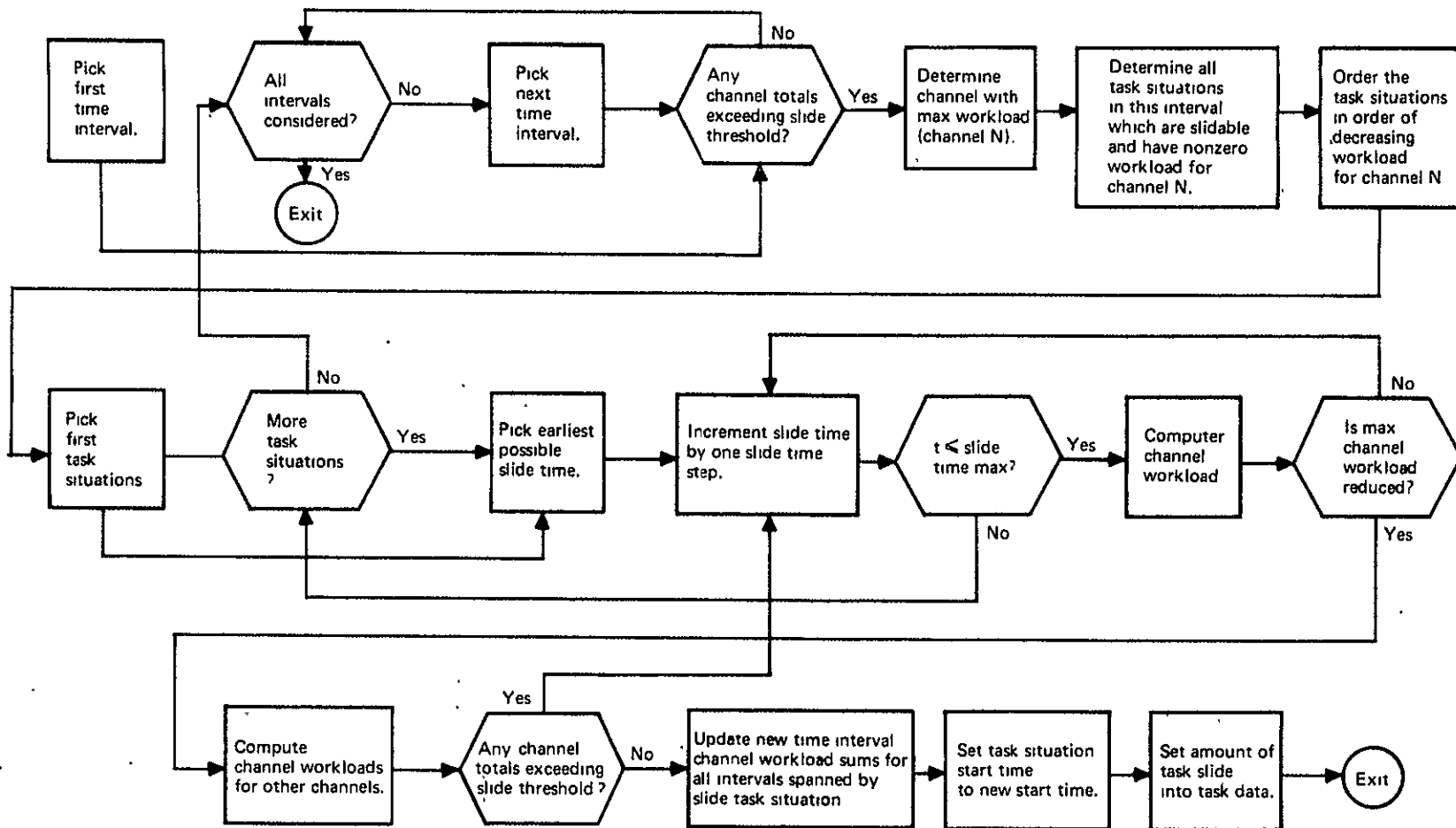
A task situation is permitted to slide only if no other time intervals will have a channel workload exceeding the slide threshold criterion as a result of the slide. A task situation slides back in time to the earliest start time possible without causing other channel workloads to be exceeded in other time intervals.

After all time intervals have been checked and all shifting is performed, the statistics for the shifted timeline are performed by the following procedure (refer to fig. 45):

- Step 1: Pick the first time interval and go to step 3.
- Step 2: Pick the next time interval and go to step 3 unless all time intervals have been considered. If all time intervals have been considered, the sliding process is finished.
- Step 3: If any channel totals in the time interval exceed the slide threshold criterion, go to step 4. Otherwise, go back to step 2.
- Step 4: Determine the channel with the maximum workload. Perform steps 5 through 12 to attempt reduction of this maximum channel workload.
- Step 5: Determine all task situations that are associated with this interval, that are slidable, and that have a nonzero workload for the channel to be reduced. List the task situations in the order of decreasing workload for the channel to be reduced.
- Step 6: Pick the first task situation and go to step 8.
- Step 7: Pick the next task situation if there are more task situations to be considered and go to step 8. Otherwise, go back to step 2.
- Step 8: Pick the earliest possible slide time for the task situation and go to step 9.
- Step 9: Increment slide time by one slide time step and go to step 10 if the resulting slide time is less than or equal to the slide maximum. Otherwise, go back to step 7.
- Step 10: If the maximum channel workload total from step 4 is reduced as a result of the slide, go to step 11. Otherwise, go back to step 9.
- Step 11: If the time intervals spanned by the task situation after sliding do not have a channel total exceeding the slide threshold as a result of the slide, the slide is permitted and step 12 is next. Otherwise, go back to step 9.
- Step 12: Update the new interval channel workload sums as a result of sliding for all intervals spanned by the slide task situation. Set the task-situation start time to the new start time and set the amount of the slide into the task information. Go back to step 3.

8.3.4 TASK-CHANNEL ACTIVITY CALCULATIONS

This set of calculations gives the percent of interval time that a task-situation channel workload contributes to an interval total channel workload if the interval total channel workload exceeds a report threshold.



^aPerformed after all task processing has been completed if this option is specified.

Figure 45.—Task-Situation Time Shift Function^a

The time intervals are first scanned to determine if any channel workload exceeds the report threshold. If an overload occurs, the task situations contributing to the workload are tagged with the time interval and channel of the overload. The workload for each task-situation channel is calculated by using the equation for W_A in section 8.3.1.2. These workloads are put into the task-channel activity report.

The analytical procedure is shown in figure 46. An example of the calculations is shown in figure 47.

8.3.5 SUBSYSTEM ACTIVITY CALCULATIONS

The purpose of the subsystem activity calculations is to measure how much of the time the subsystems are involved in workloads exceeding given thresholds. Figure 48 shows the analytical procedure used to derive three different measures of the subsystem activity.

For a given subsystem, all related task situations that contribute to a channel workload exceeding a threshold are obtained for each time interval within a phase. As a task situation is tagged, the associated channel workload contributing to the excessive workload is tagged as well. These tagged channel workloads will be referred to as channel overload contributors.

The next step is to add all channel overload contributors for a given channel and count the number N_{COC} . This sum is called the total channel overload contribution W_{OVLD} .

The next step is to ascertain the number of time intervals $N_{\Delta T}$ for each phase channel in which there are channel overload contributors and then to calculate the total interval time for a channel in which an overload occurs by using the equation

$$\Delta T_{INT} = N_{\Delta T} \Delta t$$

where Δt is the time interval.

The ratio of total channel overload contributions to total interval time is given by

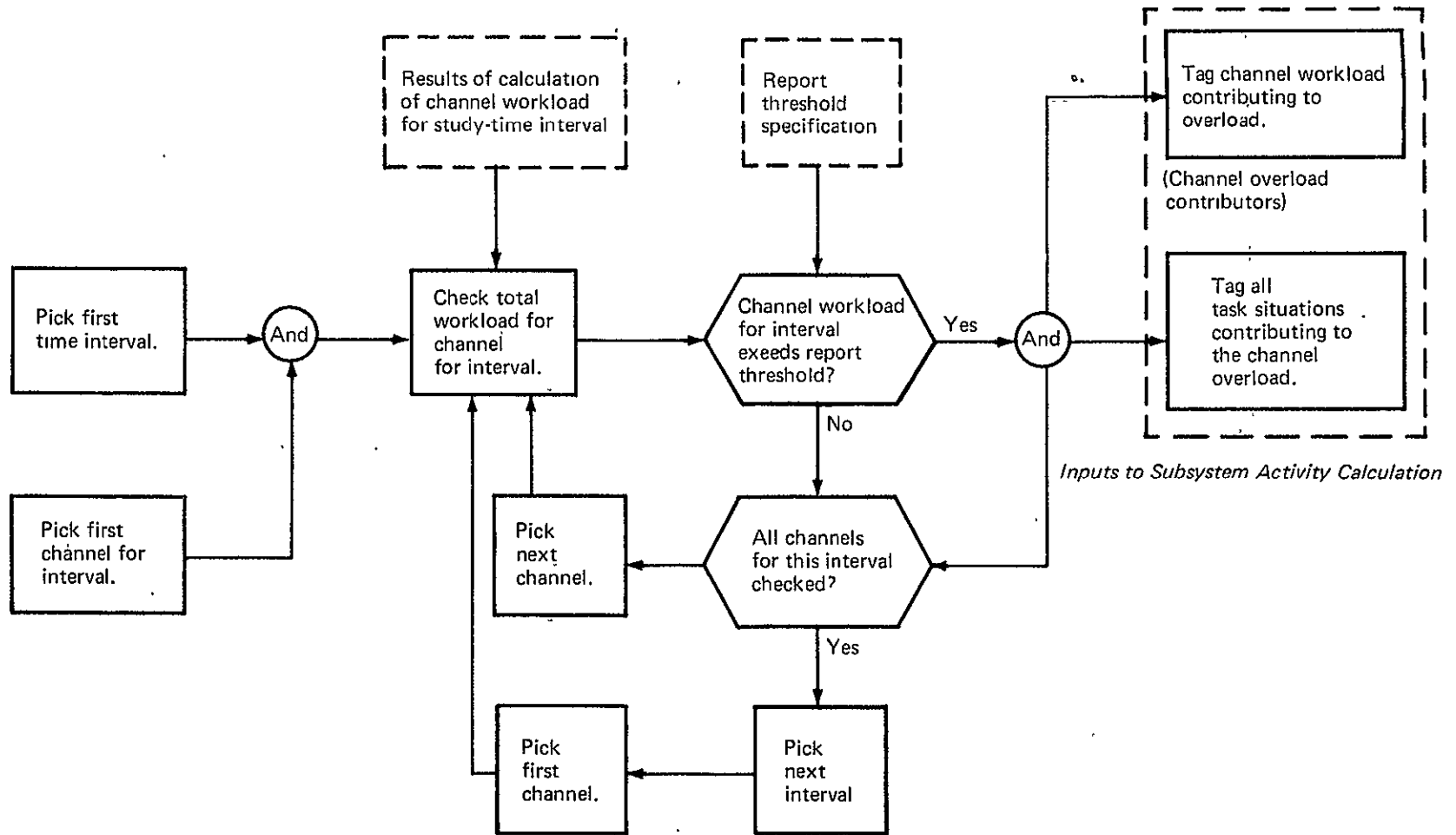
$$R_{INT} = \frac{W_{OVLD}}{\Delta T_{INT}}$$

See figure 49 for an example of interval time calculation.

The ratio of total channel overload contribution to phase total time is given by

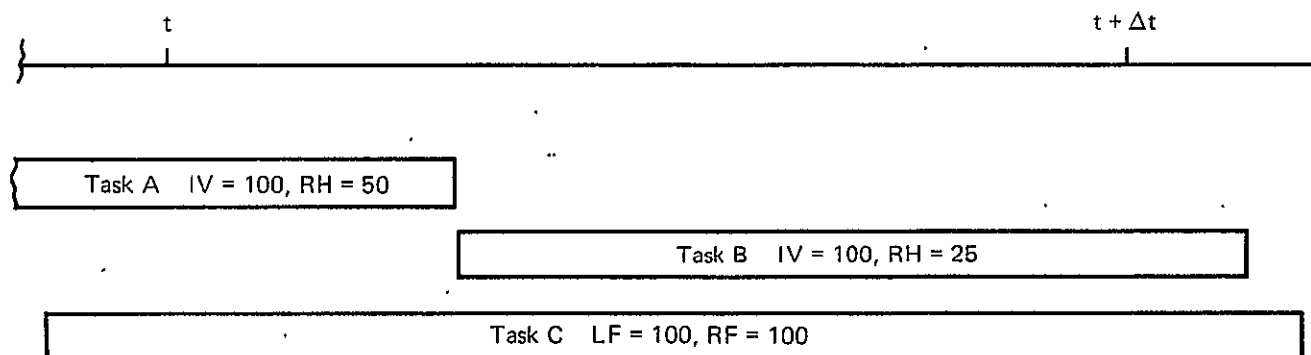
$$R_{PHS} = \frac{W_{OVLD}}{\Delta T_{PHS}}$$

where ΔT_{PHS} is the time between the phase start and the start of the next phase. See figure 50 for an example of phase time calculation.



^aThis computation is performed for each phase.

Figure 46.—Task-Channel Activity Calculations^a



Note: For the study interval t to $(t + \Delta)$, the IV channels for task A and task B would be tagged for any report threshold $< 100\%$.

Figure 47.—Example of the Task-Channel Activity Calculation

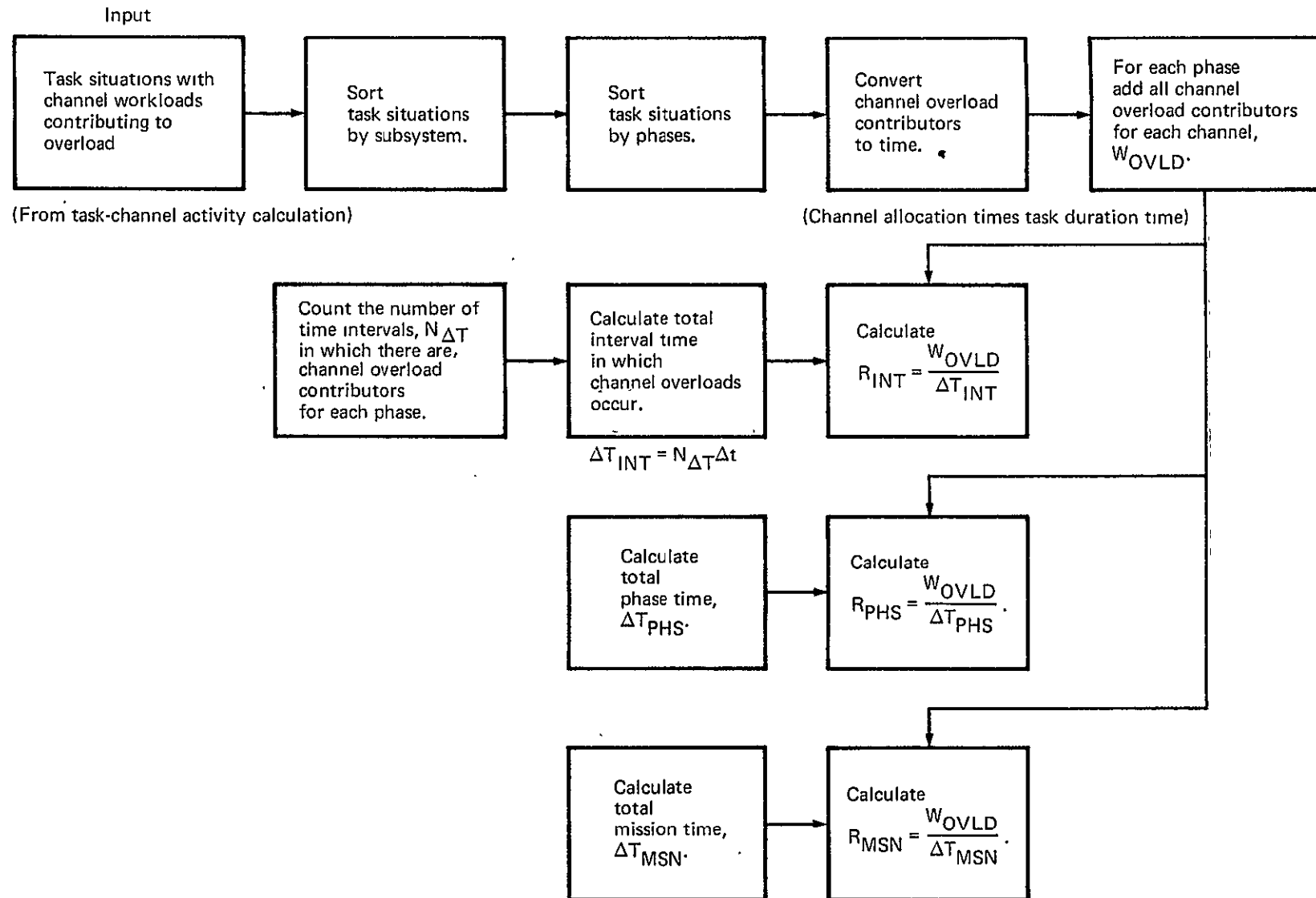
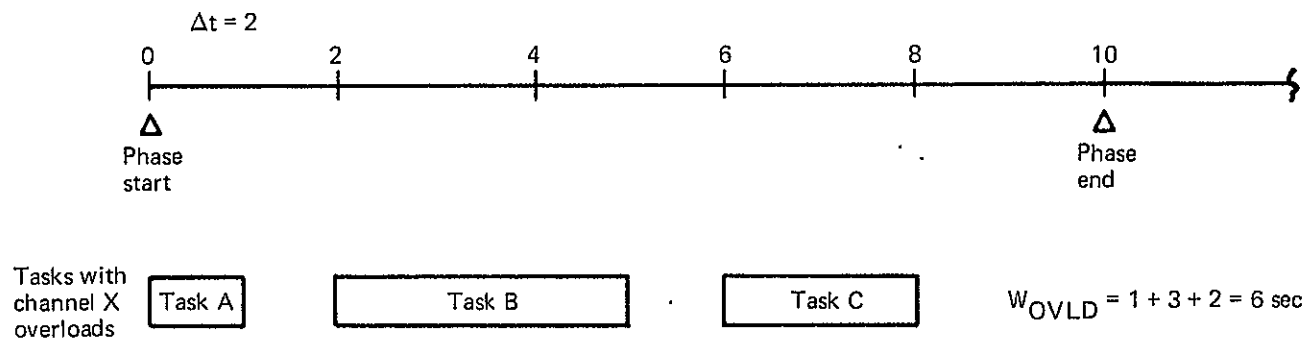


Figure 48.—Subsystem Activity Calculations



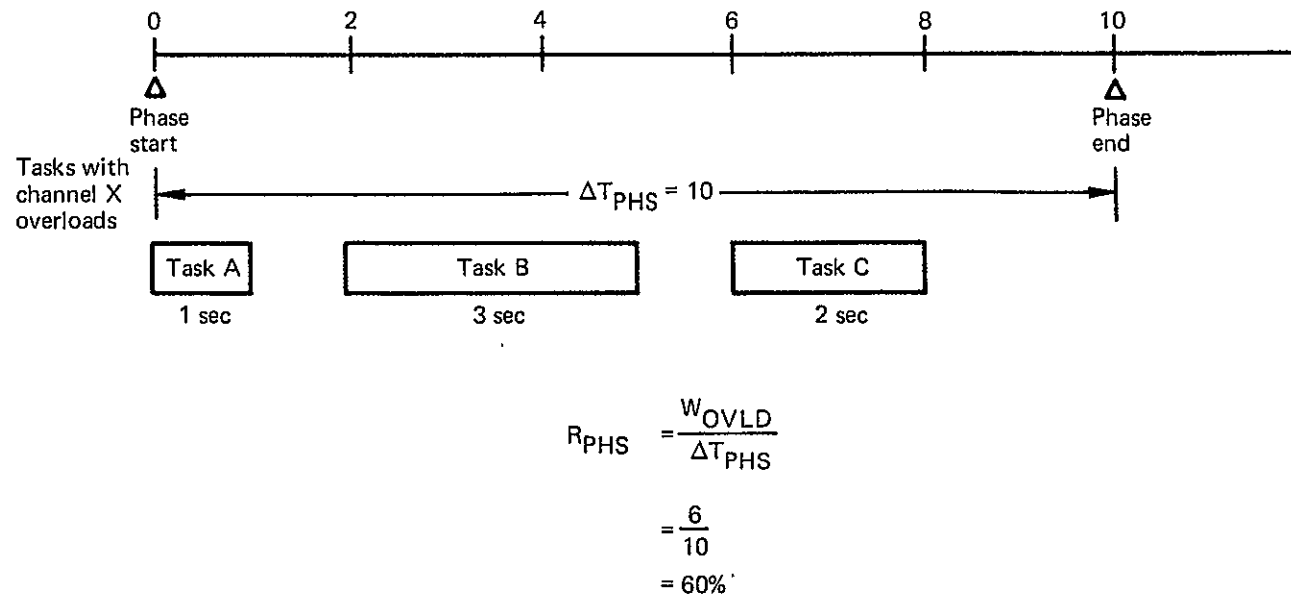
$$\begin{aligned}
 N_{\Delta T} &= \sum \text{intervals occupied by channel overloads} \\
 &= 1 + 2 + 1 \\
 &= 4 \text{ intervals}
 \end{aligned}$$

$$\Delta T_{INT} = N_{\Delta T} \Delta t = 4(2) = 8 \text{ sec}$$

$$R_{INT} = \frac{W_{OVLD}}{\Delta T_{INT}} = \frac{6}{8} = 0.75 = 75\%$$

Note: R_{INT} is the ratio of the total length of time that there is a channel overload during a phase, compared to the total time occupied by the study-time intervals in which the overloads occur.

Figure 49.—Percent Active Time of Interval Time Calculation—Example



Note: R_{PHS} is the ratio of the total length of time that there is a channel overload during a phase, compared to the total time duration of the phase.

Figure 50.—Percent Active Time of Phase Time Calculation—Example

The ratio of total channel overload contribution to mission total time is given by

$$R_{MSN} = \frac{W_{OVLD}}{\Delta T_{MSN}}$$

where ΔT_{MSN} is the time interval between mission start and mission end. See figure 51 for an example of mission time calculation.

Refer to section 8.4.2.6 for a description of how these statistical subsystem activity measures are used.

8.4 OUTPUTS

Program outputs are to tape, printer, and plotter. The tape output will contain the mission data input and the timeline analysis data generated by the task processing function of the computer program. Two classes of report outputs are specified for the TLA-1 program: digital printer and graphical plotter.

8.4.1 MISSION DATA TAPE OUTPUT

A tape will be used to store the mission data input and the processed data for later use by the report generation function. The tape will consist of two files, one containing the mission data input and the other containing the processor output used by the report generator function.

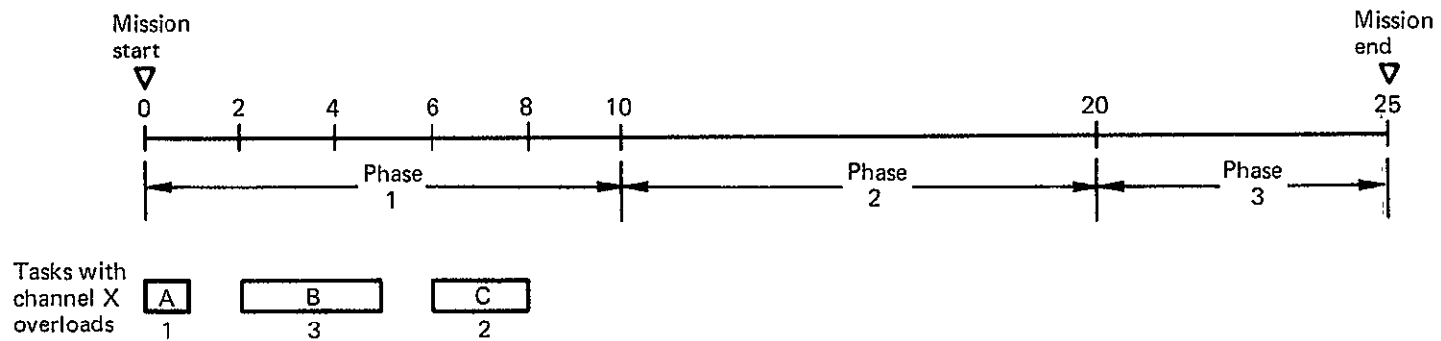
8.4.2 DIGITAL PRINTER OUTPUT

1. Mission scenario
2. Crewman workload profile
3. Crewman workload summary statistics
4. Task channel activity
5. Subsystem activity
6. Subsystem activity summary
7. Task list

The following sections describe these reports, which are generated as a result of the report requests described in section 8.2.1.3.1.

8.4.2.1 Mission Scenario Report

The mission scenario report presents a listing of specified phases and associated events, procedures, and tasks. Relative to the mission start time, the start times of the phases,



$$W_{\text{OVLD}} = 6 \text{ sec}$$

$$\Delta T_{\text{MSN}} = 25 \text{ sec}$$

$$R_{\text{MSN}} = \frac{W_{\text{OVLD}}}{\Delta T_{\text{MSN}}} = \frac{6}{25} = 0.24 = 24\%$$

Note: R_{MSN} is the ratio of the total length of time that there is a channel overload during a phase, compared to the total time duration of a mission.

Figure 51.—Percent Active Time of Mission Time Calculation—Example

procedures, and events are output. The start and end time and the activity time are output for each task in the specified phases. In addition, the amount of task shifting is output if the shifting option is specified.

The report is generated for a selected crewmember. Figure 52 is an example of the unshifted format for this report, and figure 53 is an example of the shifted format. The block in the upper left-hand corner contains the word "SHIFTED" or "UNSHIFTED" to denote whether the report contains the shifted tasks. The title block contains three labels of identification: a 40-character mission name, a 20-character configuration name, and a 20-character crewmember name. The run date is listed in the upper right-hand corner.

The report has two purposes:

1. The mission scenario report is used as final documentation to describe the tasks and procedures performed by the operators to accomplish a mission scenario. This report contains the same data as the mission timeline plot (sec. 8.4.3.4); however, it is less expensive to obtain.
2. The mission scenario report is used during the data analysis process to determine all tasks that are being performed during the various study-time intervals.¹

This report lists the tasks in the exact order that they were specified on the event/procedure coding form; therefore, if procedures and/or tasks were specified out of time sequence, they will not be listed in sequence on this report. The report must be scanned to check if the time intervals are out of sequence.

The mission scenario lists all phase event and procedure titles for each crewmember, even if the crewmember has no tasks associated with these entities. This report only indirectly shows interaction between crewmembers. The only place where crew interaction is clearly visible is on the workload analysis worksheets. (See sec. 4.1.3.)

8.4.2.2 Crewman Workload Profile Report

The crewman workload profile report gives the channel, channel groups and average channel workload for each time interval within a specified phase. The workload is in percent, and the time interval start and end times are relative to the mission start time.

Each report is identified by an indication of whether the shifted or unshifted option was used and by the run date. The report is also identified by the mission name and configuration (cockpit layout and manning), the crewmember, and the flight phase.

A sample of the report is shown in figure 54. The block in the upper left-hand corner is for printing the specified option, shifted or unshifted. The block in the upper right-hand corner is for the run date.

¹The task-channel activity report (sec. 8.4.2.4) lists only those tasks that occur during the study-time intervals that exceed the report threshold. If the report threshold was specified as 0%, these two listings would show the same tasks.

 * UNSHIFTED *

 * MISSION SCENARIO REPORT *
 * MISSION - SCENARIO 3A - ILS *
 * CONFIGURATION - NASA 515 - AFD (737) *
 * CREWMEMBER - PILOT *

XXXX

TIME INTERVAL SINCE MISSION START		TOTAL ACTIVITY TIME
BEGINNING	END	
.00		
.00		
3.00	3.90	.90
4.00	6.18	2.18
6.00	8.00	2.00
8.00	10.04	2.04
12.00	12.90	.90
14.00	14.90	.90
15.00	15.54	.54
15.50	16.04	.54
18.00	20.17	2.17
22.00	24.50	2.50
26.00	26.90	.90
26.90	27.80	.90

FLIGHT PHASE:
 EVENT/PROCEDURE
 TASK

0200 PRE-START PREP - AFD

010001 COCKPIT SAFETY
INSPECTION

7B	84 CHECK BATT SW ON
7B	57 SET DC METER SEL SW TO BATT
7B	53 MON DC VOLTS INDIC
7B	52 MON DC AMPS INDIC
7A	29 CHECK SYS B HYD PUMP SWSS OFF
40	47 CHECK LANDING GEAR LEVER IN DOWN POS.
40	05 MONITOR NOSE GEAR DOWN AND LOCKED LT ON
40	09 MONITOR LEFT/RT GEAR DOWN AND LOCKED LT ON
6A	17 CHECK W/R OFF
4E	16 CHECK FLAP LEVER AND POSITION INDIC AGREE
7P	48 MON ENG NO.1 OVRHT DETECT SW ON NORMAL
7P	49 MON ENG NO.2 OVRHT DETECT SW ON NORMAL

Figure 52.—Mission Scenario Report, Unshifted—Example

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***** * SHIFTEO * *****			***** * MISSION SCENARIO REPORT * MISSION - SCENARIO 3A - ILS * CONFIGURATION - NASA 515 - AFD 17371 * CREWMEMBER - PILOT *****			XXXX	
TIME INTERVAL SINCE MISSION START BEGINNING	END	TOTAL ACTIVITY TIME	AMOUNT SHIFTED	FLIGHT PHASE EVENT/PROCEDURE TASK			
.00				0200 PRE-START PREP - AFD			
.00				010001 COCKPIT SAFETY INSPECTION			
3.00	3.90	.90	.00	7B	84	CHECK BATT SW ON	
4.00	6.18	2.18	.00	7B	57	SET DC METER SEL SW TO BATT	
6.00	8.06	2.06	.00	7B	53	MON DC VOLTS INDIC	
8.00	10.04	2.04	.00	7B	52	MON DC AMPS INDIC	
12.00	12.90	.90	.00	7A	29	CHECK SYS B HYD PUMP SWSS OFF	
14.00	14.90	.90	.00	4D	47	CHECK LANDING GEAR LEVER IN DOWN POS.	
15.00	15.54	.54	.00	4D	05	MONITOR NOSE GEAR DOWN AND LOCKED LT ON	
15.50	16.04	.54	.00	4D	09	MONITOR LEFT/RT GEAR DOWN AND LOCKED LT ON	
18.00	20.17	2.17	.00	6A	17	CHECK W/R OFF	
22.00	24.50	2.50	.00	4E	16	CHECK FLAP LEVER AND POSITION INDIC AGREE	
25.00	26.90	.90	.00	7P	48	MON ENG NO.1 OVRHT DETECT SW ON NORMAL	
26.90	27.80	.90	.00	7P	49	MON ENG NO.2 OVRHT DETECT SW ON NORMAL	

Figure 53.—Mission Scenario Report, Shifted—Example

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***** * UNSHIFTED * *****				***** * CREWMAN WORKLOAD PROFILE REPORT * * MISSION - SCENARIO 3A - ILS * * CONFIGURATION - NASA 515 - AFD (737) * * CREWMEMBER - PILOT * * FLIGHT PHASE - PRE-START PREP - AFU * *****								XXXX		
TIME START	INTERVAL END	EXTERNAL VISION	INTERNAL VISION	LEFT HAND	RIGHT HAND	LEFT FOOT	RIGHT FOOT	COGNITION	AUDIO	VERBAL	TOTAL VISION	TOTAL MOTOR	TOTAL COMM	AVERAGE
0	5	.00	38.00	.00	20.00	.00	.00	4.00	.00	.00	38.00	5.00	.00	11.75
5	10	.00	104.80	.00	23.60	.00	.00	20.96	.00	.00	104.80	5.90	.00	32.91
10	15	.00	36.80	.00	.00	.00	.00	7.36	.00	.00	36.80	.00	.00	11.04
15	20	.00	61.60	.00	.00	.00	.00	12.32	.00	.00	61.60	.00	.00	18.48
20	25	.00	53.40	.00	.00	.00	.00	10.68	.00	.00	53.40	.00	.00	16.02
25	30	.00	100.80	.00	32.40	.00	.00	20.16	.00	.00	100.80	8.10	.00	32.26
30	35	.00	98.40	.00	50.00	.00	.00	19.68	10.80	.00	98.40	12.50	10.80	35.34
35	40	.00	16.25	.00	32.60	.00	.00	8.68	.00	.00	16.25	8.15	.00	8.27
40	45	.00	100.00	.00	100.00	.00	.00	20.00	.00	.00	100.00	25.00	.00	36.25
45	50	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
50	55	.00	71.80	.00	71.80	.00	.00	14.36	.00	.00	71.80	17.95	.00	26.03
55	60	.00	94.80	.00	69.60	.00	.00	18.96	.00	.00	94.80	17.40	.00	32.79
60	65	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
65	70	.00	100.00	100.00	100.00	.00	.00	20.00	.00	.00	100.00	50.00	.00	42.50
70	75	.00	100.00	100.00	100.00	.00	.00	20.00	.00	.00	100.00	50.00	.00	42.50
75	80	.00	100.00	100.00	100.00	.00	.00	20.00	.00	.00	100.00	50.00	.00	42.50
80	85	.00	40.00	40.00	40.00	.00	.00	8.00	.00	.00	40.00	20.00	.00	17.00

Figure 54.—Crewman Workload Profile Report—Example

This report is used in conjunction with the workload histogram plot (sec. 8.4.3.2) and the mission scenario report (sec. 8.4.2.1) to diagnose the cause of high workload situations. By looking at the histogram, the analyst determines the approximate time intervals in which unusually high workloads exist and then refers to the crewman workload profile report for the time intervals in question. The analyst scans the various workload values to isolate the channels that contribute to the high workload.

If the channel workload value for any study-time interval is in excess of 100%, one of the following two situations exists:

1. Most likely, an input data error has occurred.
 - a. Tasks have been inadvertently overlapped.
 - b. Most likely, a channel allocation specified for a task exceeds 100% because of keypunch errors where a channel allocation value for the task is not right-adjusted in the appropriate field on the task data specification. (Refer to the task list.)
2. A true work overload condition exists because of too many tasks to be performed during a time interval.

The analyst refers to the mission scenario report to determine the tasks that are to be performed during each time interval.

8.4.2.3 Crewman Workload Summary Statistics Report

The crewman workload summary statistics report presents the average workload, the workload variance, and the standard deviation of the workload for all channels, all channel groups, and the weighted average channel over a phase. In addition, the sum of the workloads and the sum of the squares of the workloads are given.

Figure 55 is a sample of this report. In the upper left-hand corner of the report is a block for printing whether the report is for the task shifted or unshifted option. In the upper right-hand corner is a block to print the run date. Each report is identified by the mission name and configuration, the crewmember, and the flight phase.

The crewman workload summary statistics report lists the data that are plotted on the workload summary plot (sec. 8.4.3.3) and the channel activity summary plot (sec. 8.4.3.1). In addition to these data, the intermediate calculation results are listed. Since the graphical plots of the data are more easily interpreted, they are recommended; however, this report can be used to determine how the plotted average and 1σ values were obtained.

8.4.2.4 Task-Channel Activity Report

The task-channel activity report gives a listing of all tasks that contribute to a channel workload exceeding a specified threshold. The channel workloads that cause the threshold to be exceeded are called channel overload contributors and will be offset by a

 * UNSHIFTED *

 * CREWMAN WORKLOAD SUMMARY STATISTICS REPORT *
 * MISSION - SCENARIO 3A - JLS *
 * CONFIGURATION - NASA 515 - AFD (737) *
 * CREWMEMBER - PILOT *
 * FLIGHT PHASE - PPF-START PREP - AFD *
 * * *

XXXX

CHANNEL	SUM X	SUM Y SQUARED	AVERAGE LOAD	VARIANCE	STANDARD DEVIATION
EXTERNAL VISION	52.00	400.0	.25	2.235	1.492
INTERNAL VISION	11070.5	1261001.9	52.72	2244.961	47.385
LEFT HAND	2038.00	140114.0	9.46	616.812	24.834
RIGHT HAND	6695.60	501780.5	31.98	1279.422	35.761
LEFT FOOT	430.00	35300.0	2.05	164.687	12.833
RIGHT FOOT	430.00	35300.0	2.05	164.687	12.833
COGNITION	2904.40	75182.4	13.83	167.532	12.942
AUDITORY	1252.80	52592.6	5.97	215.879	14.692
VERBAL	648.00	10534.3	3.09	79.114	8.895
TOTAL VISION	11122.5	1266422.7	52.96	2240.777	47.339
TOTAL MOTOR	2290.00	10537.0	11.39	278.070	16.672
TOTAL COMMUNICATIONS	1920.80	87959.8	9.05	338.540	18.396
AVERAGE	4579.64	172089.6	21.81	345.534	18.589

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Figure 55.—Crewman Workload Summary Statistics Report—Example

symbol "*" on each side of the value. In addition, the study-time segment number, task code, task name, task start time relative to the mission start time, task duration time, and situation number are printed.

A sample of the report is shown in figure 56. The report is identified by a block in the upper left-hand corner stating whether the report is for shifted or unshifted task, by a run date in the upper right-hand corner, and by a title block. The title block contains the mission name and configuration, the crewmember, the flight phase, the study-time interval, and the threshold value (in percent) for the report.

The task-channel activity report is used to report the results of using the report threshold, which can be thought of as an adjustable "filter" that screens out only those tasks that contribute to workloads in excess of a specified value. The analyst could use this format on a first iteration to screen out the tasks that cause workload in excess of 100% (sec. 8.4.2.2) and that are caused by input data errors. This would eliminate using the workload histogram and mission scenario report (as described in sec. 8.4.2.2) to accomplish the same screening process.

On successive iterations, the task-channel activity report would be used as the report threshold adjusted by the analyst as he explores how sensitive a particular scenario or scenario segment is to various overload criteria. If 0% were specified for the report threshold, all tasks would be listed.

This report is used with the subsystem activity report (sec. 8.4.2.5) and subsystem activity summary report (sec. 8.4.2.6) to determine which subsystem contributes to work overload. Prior to requesting the subsystem reports, the analyst could use the task-channel activity report for an indication of which subsystems seem to be involved most often in work overloading. (The analyst will usually have a good idea which subsystems will be involved when he is laying out the data on the workload analysis worksheets.) The report is also used in conjunction with the subsystem activity reports to determine how the various subsystems interact during periods of high workload.

8.4.2.5 Subsystem Activity Report

The subsystem activity report provides the same information for tasks as the task-channel activity report (sec. 8.4.2.4) but reorders the task under the subsystems used in performing the task. In addition, a measure of the channel overload contributors is output for each channel and for each subsystem specified. The channel measures are the total of the channel overload contributors in seconds during the phase, the total study-interval time containing the tasks that exceed the report threshold, the percent of total study-interval time that the channel workload exceeds the threshold, the percent of mission time that the channel workload exceeds the threshold, and the percent of phase time that the channel workload exceeds the threshold. Figure 57 is a sample of this output.

The subsystem activity report is used with the subsystem activity summary report (sec. 8.4.2.6) and the task-channel activity report (sec. 8.4.2.4) to isolate and study

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	620	2H	29 MONITOR ALT ENG MODE LT GREEN - ALT ENG MODE ENGAGED	1	1	0	* 1*	0	0	0	0	0	0	0
	620	2K	17 MON 32 NM MAP VIDEO	1	2	0	* 2*	0	0	0	0	0	0	0
27	621	1P	15 MONITOR CALL-OUT	3	4	0	0	0	0	0	0	1	* 4*	0

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Figure 56.—(Concluded)

```

*****
* UNSHIFTED. *
*****
SUBSYSTEM ACTIVITY REPORT
MISSION - ENGINE FIRE-NOISE
          ABATEMENT CLIMB
CONFIGURATION - NASA-515 APD COCKPIT
CREW MEMBER - CO-PILOT
FLIGHT PHASE - ENGINE FIRE - NOISE
          ABATE CLB.
PHASE TIME - 2325 TO 2465
          1. 2 MIN 20 SEC
TOTAL MISSION TIME - 41 MIN
          5 SEC
TIME INTERVAL - 5
REPORT THRESHOLD - 70
*****

```

MISSION		TASK		DURATION		CHANNEL ACTIVITY - SECS									
TIME	TIME	TASK CODE	TASK	TIME	TIME	EV	IV	LH	RH	LE	RF	COG	AUD	VBL	
SEGMENT (MINUTES)	SUBSYS.	NO.	NAME	SITUATION (SECONDS)											

* SUBSYSTEM - FIRE/OVERHEAT/SMOKE DETEC															

6	619	7P	15 MON ENG NO.1 FIRE	4	5	0	*	2*	0	0	0	0	0	0	
			WARNING LT ON												
619	7P	18	ROTATE ENG NO.1 FIRE	2	2	0	*	2*	2	0	0	0	0	0	
			WARNING SW HANDLE TO												
			LEFT												
619	7P	27	MON L BOTTLE	2	0	0	*	0*	0	0	0	0	0	0	
			DISCHARGE LT ON												

Figure 57.—Subsystem Activity Report—Example

				TASK DURATION		CHANNEL ACTIVITY - SECS									
TIME	MISSION	TASK CODE	TASK	SITUATION	TIME										
SEGMENT	(MINUTES)	SUBSYS. NO.	NAME			FV	IV	LH	RH	LF	RF	COG	AUD	VBL	
10	619	7P	16 MON ENG NO.1 FIRE WARNING LT OFF	3	15	0	*	5*	0	0	0	0	1	0	0
11	620	7P	16 MON ENG NO.1 FIRE WARNING LT OFF	3	15	0	*	5*	0	0	0	0	1	0	0
TOTAL ACTIVE TIME IN THIS PHASE						0	14	0	0	0	0	0	0	0	0
WHERE THRESHOLD IS EXCEEDED (SEC)															
TOTAL INTERVAL TIME IN THIS PHASE						0	15	0	0	0	0	0	0	0	0
WHERE THRESHOLD IS EXCEEDED (SEC)															
PERCENT ACTIVE TIME OF INTERVAL TIME						0	95	0	0	0	0	0	0	0	0
PERCENT ACTIVE TIME OF MISSION TIME						0	1	0	0	0	0	0	0	0	0
PERCENT ACTIVE TIME OF PHASE TIME						0	10	0	0	0	0	0	0	0	0

Figure 57.—(Concluded)

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specified subsystem involvement in work overloads. The subsystem activity report is referred to after the subsystem activity summary report is studied to determine the exact tasks that are associated with a specified subsystem and that are being performed at a specific time interval during selected phases. The stars (*) flag the channels that contribute to the overload.

The tabulations at the end of each subsystem activity report show the intermediary and final computations that are listed on the subsystem activity summary report for the specified places and subsystems. (Refer to secs. 8.3.5 and 8.4.2.6 for discussions of the derivation and use of these subsystem activity computations.)

The data shown in the report title block list the parameters that are used in the various computations.

8.4.2.6 Subsystem Activity Summary Report

The subsystem activity summary report summarizes the results from the subsystem activity report. For all channel activity exceeding the report threshold, the report restates the percent of phase time and the percent of mission time that the channel is active. The active time is the sum of the time that the specific channel workload exceeds the specified report threshold. The interval time is the sum of the study intervals containing the tasks that have a specific channel workload exceeding the report threshold.

In addition, the report summarizes across all phases and gives the percent of active time to interval time, and the percent of active time to mission time.

Each report will be identified by the mission and configuration, the crewmember, the report threshold, the date, and an indication of whether the report is with the task shifting option. Figure 58 is a sample of this report.

The subsystem activity summary report is used as a means of scanning an entire mission to quickly spot the subsystems/phases/channels that merit closer inspection because they are involved in high workloading. To request this report, the analyst has to judge which subsystems are most likely to be involved in high workload and also has to specify a work overload threshold criterion, which narrows his attention to candidate subsystems. The next problem is to isolate the various subsystems, phases, and channels that require more detailed inspection and analysis. Each analyst will develop his own logical scanning process to home in on these levels of indenture. (This report was created during the development of TLA-1 and, subsequently, has been used enough to determine all the ways in which it could be used.) The following logic has been used:

1. Which subsystems are involved?
 - a. Scan each page.
 - b. Set aside any page that has all zeros. (No further analysis is required.)

 * SHIFTED *

A - ACTIVE TIME PERCENTAGE OF INTERVAL TIME
 B - ACTIVE TIME PERCENTAGE OF PHASE TIME
 C - ACTIVE TIME PERCENTAGE OF MISSION TIME

 * SUBSYSTEM ACTIVITY SUMMARY REPORT *
 * MISSION - SCENARIO 3A - ILS *
 * CONFIGURATION - NASA 515 - AFD (737) *
 * CREWMEMBER - PILOT *
 * REPORT THRESHOLD - 50 *

XXXX

 * SUBSYSTEM - PRIMARY ATTITUDE CONTROLS *

PHASE	INT. VISION			EXT. VISION			LEFT HAND			RIGHT HAND			LEFT FOOT			RIGHT FOOT			COGNITIVE			AUDITORY			VERBAL		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
PRE-START PREP - AFD	0	0	0	72	2	0	50	0	0	59	1	0	40	0	0	40	0	0	0	0	0	0	0	0	0	0	0
ENGINE START	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TAXI -BEFORE TAKEOFF (AFD)	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	30	0	0	7	0	0	0	0	0	0	0	0
TAKEOFF (AFD)	0	0	0	0	0	0	115	5	0	115	5	0	90	4	0	90	4	0	33	2	0	0	0	0	0	0	0
NOISE ABATEMENT LIMB - AREA NAV (AFD)	0	0	0	0	0	0	0	0	0	40	0	0	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0
CRUISE - AREA NAV	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DESCENT - AFD	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
APPROACH AND LANDING -ILS (AFD)	0	0	0	0	0	0	150	2	0	100	1	0	100	1	0	100	1	0	0	0	0	0	0	0	0	0	0
TAXI - AFTER LANDING	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SHUTDOWN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	0	0	0	72	0	0	111	0	0	76	0	0	72	0	0	72	0	0	19	0	0	0	0	0	0	0	0

Figure 58.—Subsystem Activity Summary Report—Example

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2. Which phases are involved for this subsystem?
 - a. Select the page(s) that seem to have the most nonzero values.
 - b. Set the others aside for later analysis.
3. For this subsystem and these phases, which channels are involved?
 - a. Focus attention on those phases where there are nonzero values.
 - (1) The A values show the relative ranking of how much the channels are involved in work overloading.
 - (2) For a given phase, the B values give a relative ranking of how much time during the phase the various channels are involved in overloading.
 - (3) For a given phase, the C values give a relative ranking of how much time the various channels are involved in overloading during the total mission. (Note: A zero in the C columns indicates that this value is less than 1%.)
 - b. Ignore phases with all zeros.
4. From the preceding relative measures, rank the subsystem, phases, and channels in the order in which they should be investigated.
5. Go to the subsystem activity reports to determine which tasks and time intervals are involved for the subsystem during the phases to be studied.
6. Go to the task-channel activity report to determine the other tasks that contribute to the work overload during the time intervals in question.
7. To relieve the overload, do one of the following:
 - a. Change the procedure.
 - b. Give task(s) to another crewmember.
 - c. Change the design of the hardware/software.

8.4.2.7 Task List Report

The task list report lists all tasks for a mission by task number and gives the task name, situations, duration times, and channel workloads. The sole purpose of this report is to provide the analyst with an easy-to-read task catalog. Figure 59 is a sample of this report. The only data analysis involved is that the analyst uses this report to scan for keypunch errors on the task data specification.

TASK			S	DUR	CHANNEL ACTIVITY - PERCENT OF DUR TIME									
CODE	NO.	TASK NAME/DESCRIPTION			I	TIME	EV	IV	LH	RH	LF	RF	COG	AUD
SUBSYS	NO.	TASK NAME/DESCRIPTION	T	(SEC)										
18	01	MON VHF-2L FREQ IND	1	.75	0	100	0	0	0	0	0	20	0	0
			2	4.88	0	100	0	0	0	0	0	20	0	0
			3	5.08	0	100	0	0	0	0	0	20	0	0
18	02	SET VHF-2L FREQ - WHOLE NOS	1	2.20	0	10	100	0	0	0	0	20	0	0
			2	2.90	0	10	100	0	0	0	0	20	0	0
			3	2.40	0	10	0	100	0	0	0	20	0	0
			4	3.10	0	10	0	100	0	0	0	20	0	0
18	03	SET VHF-2L FREQ - FRACTIONS	1	1.98	0	10	100	0	0	0	0	20	0	0
			2	1.98	0	10	0	100	0	0	0	20	0	0
18	04	ADJ VHF-2 VOLUME	1	2.00	0	10	100	0	0	0	0	20	0	0
			2	2.09	0	10	100	0	0	0	0	20	0	0
			3	2.09	0	10	0	100	0	0	0	20	0	0
			4	2.17	0	10	0	100	0	0	0	20	0	0
18	05	SET VHF-2 COMM TFR SW TO LEFT	1	1.45	0	100	100	0	0	0	0	20	0	0
			2	2.39	0	100	0	100	0	0	0	20	0	0
			3	1.45	0	100	100	0	0	0	0	20	0	0
			4	2.30	0	100	100	0	0	0	0	20	0	0
18	06	SET VHF-2 COMM TFR SW TO RIGHT	1	1.45	0	100	100	0	0	0	0	20	0	0
			2	2.39	0	100	0	100	0	0	0	20	0	0
			3	1.45	0	100	100	0	0	0	0	20	0	0
			4	2.39	0	100	100	0	0	0	0	20	0	0
18	07	MON VHF-2R FREQ IND	1	.76	0	100	0	0	0	0	0	20	0	0
			2	4.01	0	100	0	0	0	0	0	20	0	0
			3	4.86	0	100	0	0	0	0	0	20	0	0
			3	4.86	0	0	0	0	0	0	0	0	0	0
18	08	SET VHF-2R FREQ - WHOLE NOS	1	2.03	0	10	100	0	0	0	0	20	0	0
			2	2.08	0	10	100	0	0	0	0	20	0	0
			3	2.03	0	10	0	100	0	0	0	20	0	0
			4	2.98	0	10	0	100	0	0	0	20	0	0
18	09	SET VHF-2P FREQ - FRACTIONS	1	1.98	0	10	100	0	0	0	0	20	0	0
			2	1.98	0	10	0	100	0	0	0	20	0	0
18	10	SET COMM 2 MIC SEL SW TO VHF-2	1	2.86	0	100	100	0	0	0	0	20	0	0
			2	1.99	0	100	0	100	0	0	0	20	0	0
			3	2.92	0	100	0	100	0	0	0	20	0	0
18	11	SET COMM 2 VHF-2 COMM RECVR SW TO ON	1	2.09	0	100	0	100	0	0	0	20	0	0
			2	1.52	0	100	0	100	0	0	0	20	0	0
			3	2.39	0	100	100	0	0	0	0	20	0	0
			4	1.44	0	100	100	0	0	0	0	20	0	0
18	12	SET COMM 2 VHF-2 COMM RECVR SW TO OFF	1	2.09	0	100	0	100	0	0	0	20	0	0
			2	1.52	0	100	0	100	0	0	0	20	0	0
			3	2.39	0	0	100	100	0	0	0	20	0	0
			4	1.44	0	100	100	0	0	0	0	20	0	0

Figure 59.—Task List Report—Example

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8.4.3 GRAPHICAL PLOTTER OUTPUT

The graphic output consists of the following plots: (1) channel activity summary bargraph, (2) workload histogram, (3) workload summary bargraph, and (4) mission timeline chart. The plots are generated by input requests, which are specified in section 8.2.1.3.2. The following sections describe the plots.

8.4.3.1 Channel Activity Summary Plot

This bargraph presents either the average and standard deviation or only the average of the channel workload for each channel as well as for the weighted channel average. The bargraph is for a specified phase within a mission and configuration, for a specified crewman, and for either the shifted or unshifted option. Figure 60 is a sample of the channel activity summary bargraph, which is identified by the mission name and configuration, the flight phase, a specified crewmember, the data, and a label denoting whether the bargraph is with optional shifted or unshifted tasks.

If the plotted bar exceeds the margin of 150%, the value of the average + 1σ (if optionally selected) is printed on the plot in place of the bar.

The channel activity summary plot shows the average load and standard deviation data that are found on the crewman workload summary statistics report (sec. 8.4.2.3). This data format would be used primarily as final documentation.

8.4.3.2 Workload Histogram Plot

The workload histogram is a plot of a channel, channel group, or weighted average workload as a function of elapsed mission time. The histogram provides for one or more configurations of a mission, is associated with a specified crewman, and is for a specified shifted or unshifted option.

Figure 61 is a sample of this type of plot for a single mission, and figure 62 is an example showing multiple missions. The plot is identified by the shifted or unshifted option, the run date, the mission name, the crewmember, and the configurations. A specified threshold line is also plotted. Under the histogram, the plot will also have a block that can later be used to draw an altitude profile.

The workload histogram plot is one of the most useful data formats and is used during all iterations. Early iterations quickly and clearly show high workload periods. Task data input errors will show up as unusually high spikes. On successive iterations, the histogram would be plotted for various channels as the analyst homes in on the specific nature of overloads.

Extremely busy periods can be expanded on some iterations by dropping all noncritical phases. The program will treat the remaining phase(s) as the whole mission and will therefore change the histogram time scale accordingly.

UNSHIFTED

CHANNEL ACTIVITY SUMMARY
MISSION - SCENARIO 3A - ILS

XXXX

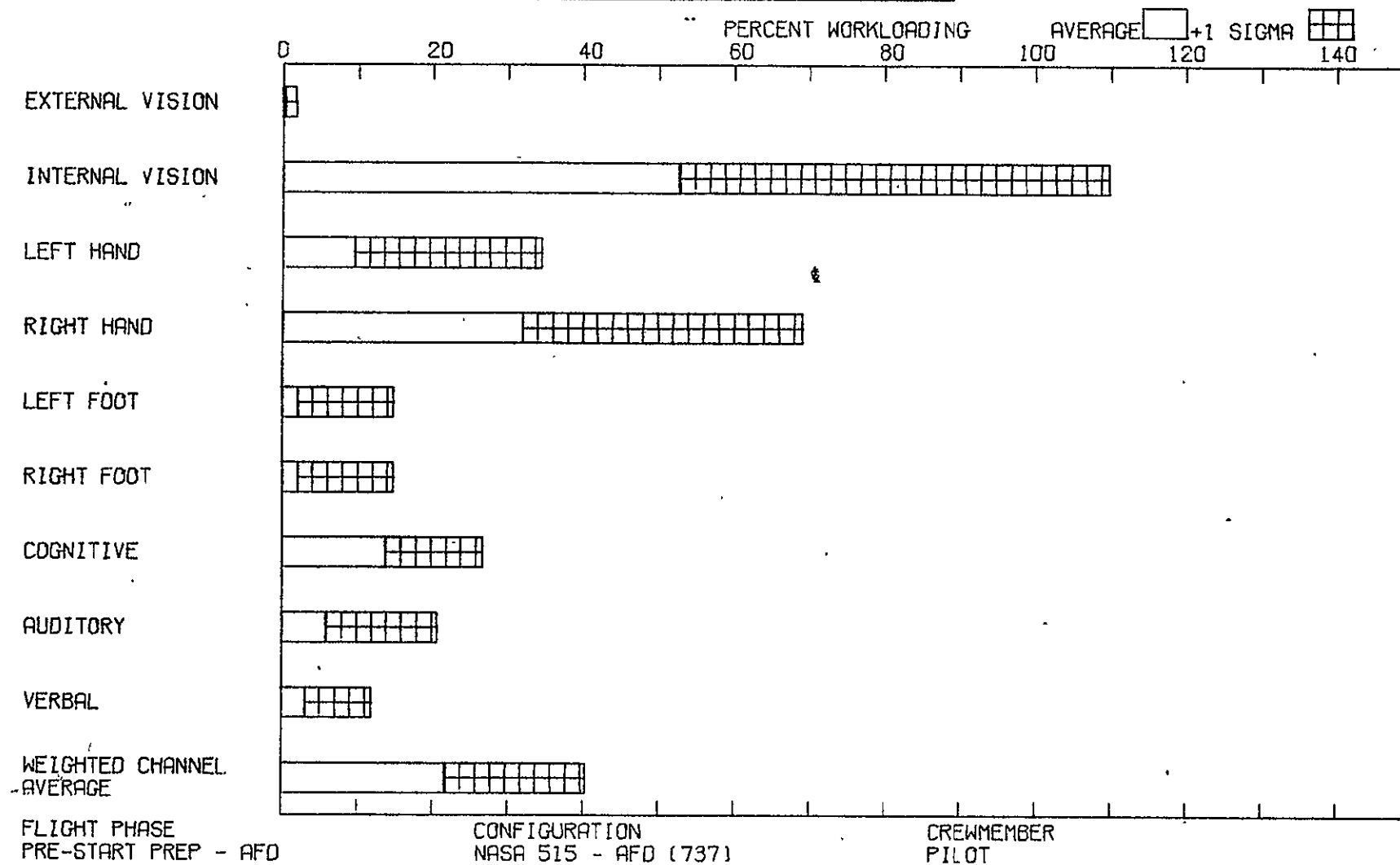


Figure 60.—Channel Activity Summary Plot—Example

UNSHIFTED
XXXX

WORKLOAD HISTOGRAM
CREWMEMBER - PILOT
CHANNEL - WEIGHTED AVERAGE CHANNEL

MISSION
SCENARIO 3A - ILS

CONFIGURATION
NASA 515 - AFD (737)

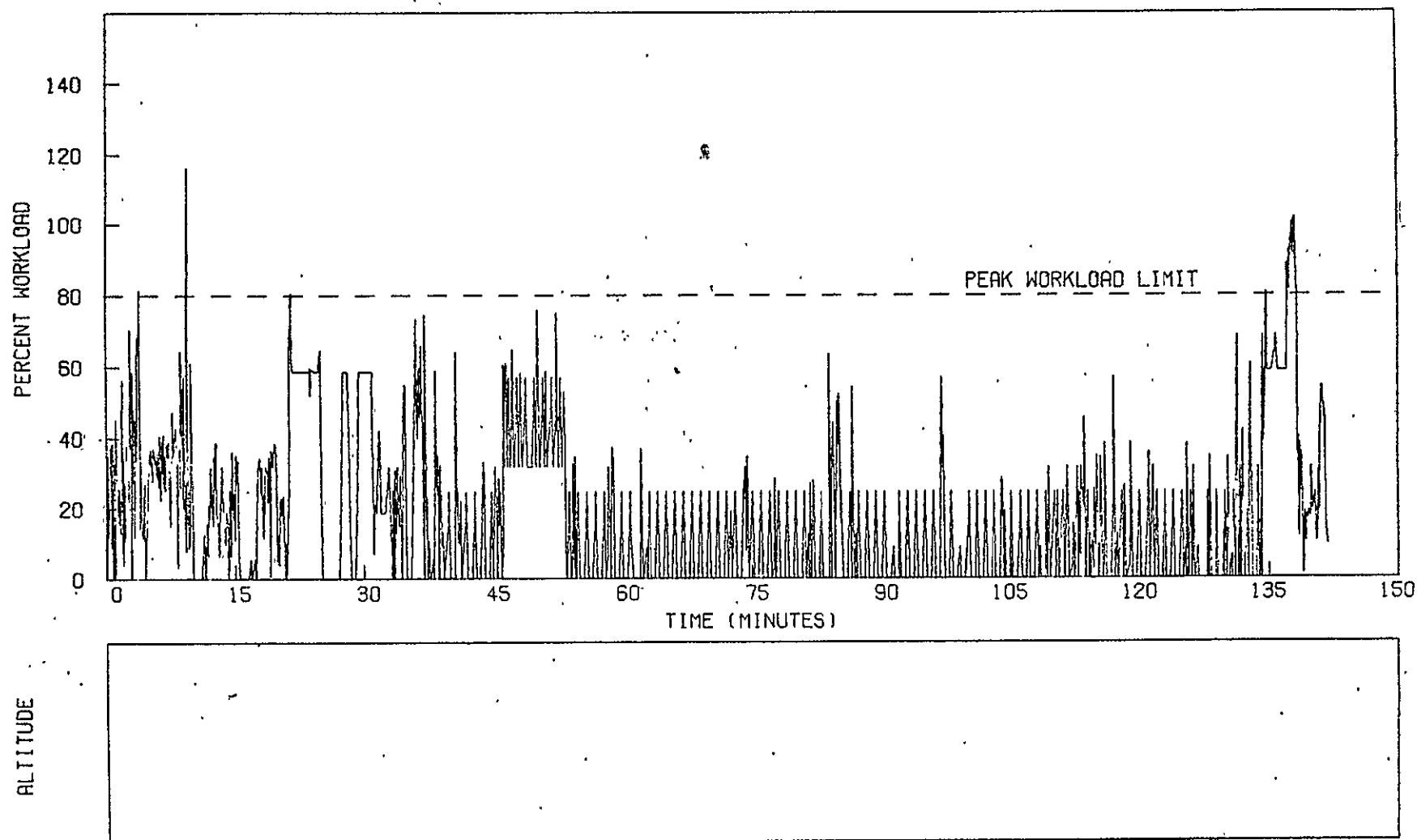


Figure 61.—Workload Histogram Plot, Single Mission—Example

UNSHIFTED
XXXX

WORKLOAD HISTOGRAM
CREWMEMBER -- PILOT
CHANNEL -- WEIGHTED AVERAGE CHANNEL

MISSION
SCENARIO 1A - ILS
SCENARIO 3A - ILS
SCENARIO 4A - MLS

CONTINGENCY
NASA 510 - FFD (737)
NASA 511 - AFD (737)
NASA 512 - AFD (737)

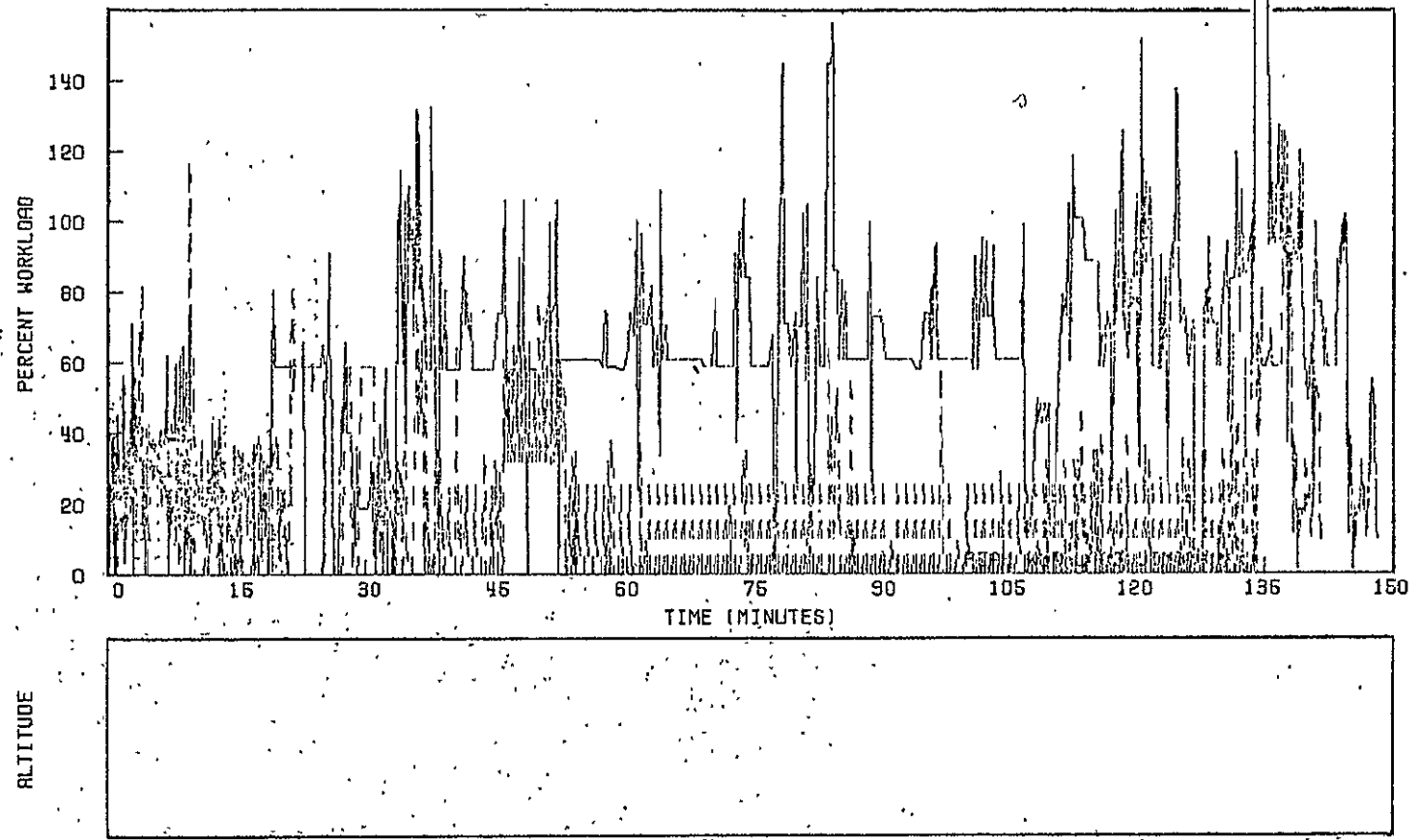


Figure 62.—Workload Histogram Plot Multiple Missions—Example

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Using the comparative plot option, the analyst can plot as many as three crewmembers for one mission and as many as three different missions for any channel, channel total, or average. This format is ideal for final documentation, because the plotted data can be readily interpreted.

8.4.3.3 Workload Summary Plot

This bargraph gives either a summary of the average workload and workload standard deviation or only the average workload for each channel group (vision, motor, communication, and cognitive) and for the weighted average channel. The bargraph is for a specified crewmember and phase and for as many as three configurations of a mission.

Figure 63 is a sample of the bargraph showing a single mission, and figure 64 shows data from two missions. The bargraph is further identified by specifying in the upper left-hand corner whether the graph is for shifted or unshifted tasks. The run date is placed in the upper right-hand corner.

If the plotted bar exceeds the margin of 150%, the value of the average + 1 σ (if optionally selected) is printed on the plot in place of the bar.

The workload summary plot is used for final documentation to plot some of the results listed in the crewman workload summary statistics report. This format offers a way to show how up to three different crewmembers, missions, or configurations compare. It is of little value early in the workload analysis.

8.4.3.4 Mission Timeline Plot

This chart presents an interval bar along a timeline to show when a task situation is in effect. The chart is for a specified phase and crewmember within a given mission and configuration and for an optional shifted or unshifted task catalog. Each event and procedure start time within the phase is indicated by a pointer "v." Tasks are listed from the top to the bottom of the chart in their order of occurrence within the mission.

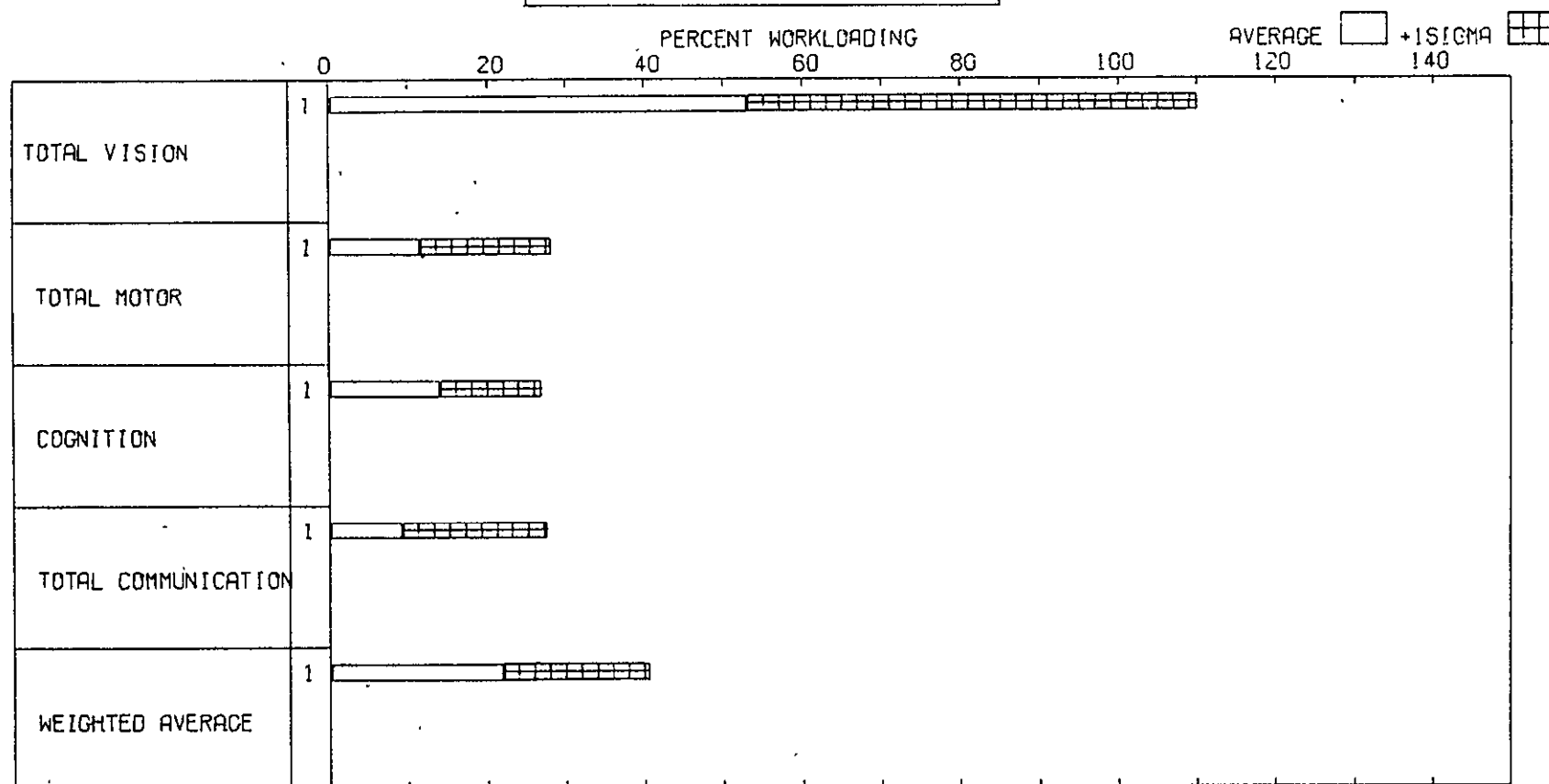
Figure 65 is a sample of this plot. The run date will be put in the upper right-hand corner of the plot. Due to the large number of expected tasks, there will be no blank lines between task/procedure/event descriptions.

The mission timeline plot is provided as a means to show the sequence of tasks. The same data as found in the mission scenario report (sec. 8.4.2.1) are shown in a graphical format, which would be used only for final documentation and then with discretion. Only 15 to 30 tasks will be listed per page, and a long mission will require many of these plots. This data output is therefore relatively expensive.

UNSHIFTED

WORKLOAD SUMMARY
CREWMEMBER - PILOT

XXXX



MISSION
1 SCENARIO 3A - ILS

CONFIGURATION
NASA 515 - AFD (737)

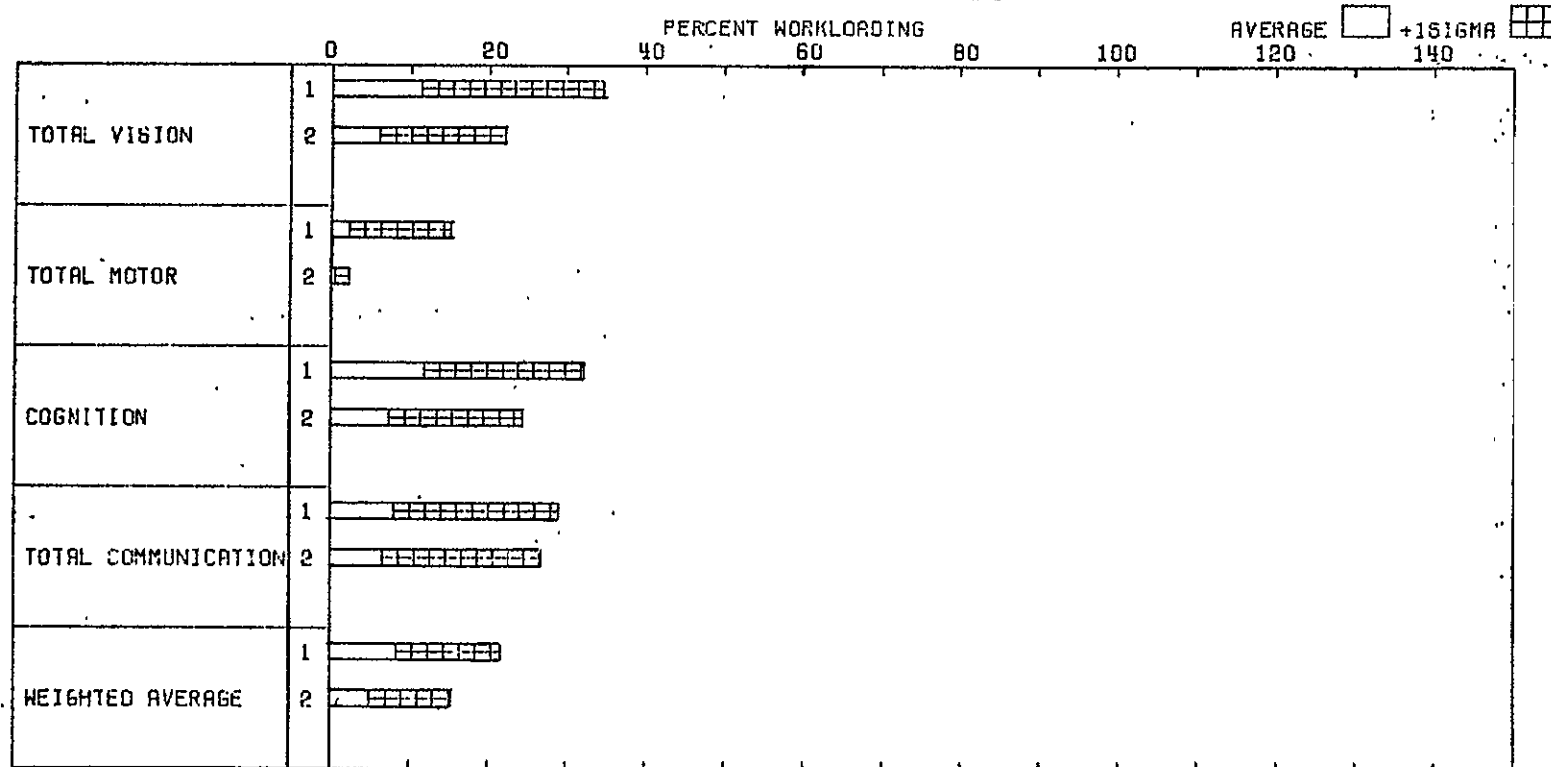
FLIGHT PHASE
PRE-START PREP - AFD
PREP - AFD

Figure 63.—Workload Summary Plot, Single Mission—Example

SHIFTED

WORKLOAD SUMMARY CREWMEMBER - PILOT

XXXX



MISSION	CONFIGURATION	FLIGHT PHASE
1 SCENARIO 3A - ILS	NASA 515 - AFD (737)	APPROACH AND LANDING
2 SCENARIO 3B - ILS WITH MALFUNCTIONS	NASA 516 - AFD (737)	-ILS (AFD) APPROACH AND LANDING -ILS (AFD) -PILOT INCAPACITATED

Figure 64.—Workload Summary Plot, Multiple Missions—Example

UNSHIFTED

MISSION TIMELINE
 MISSION - SCENARIO 3A - IL6
 CONFIGURATION - NASA 515 - AFD (737)
 FLIGHT PHASE - ENGINE START
 CREWMEMBER - PILOT

XXXX

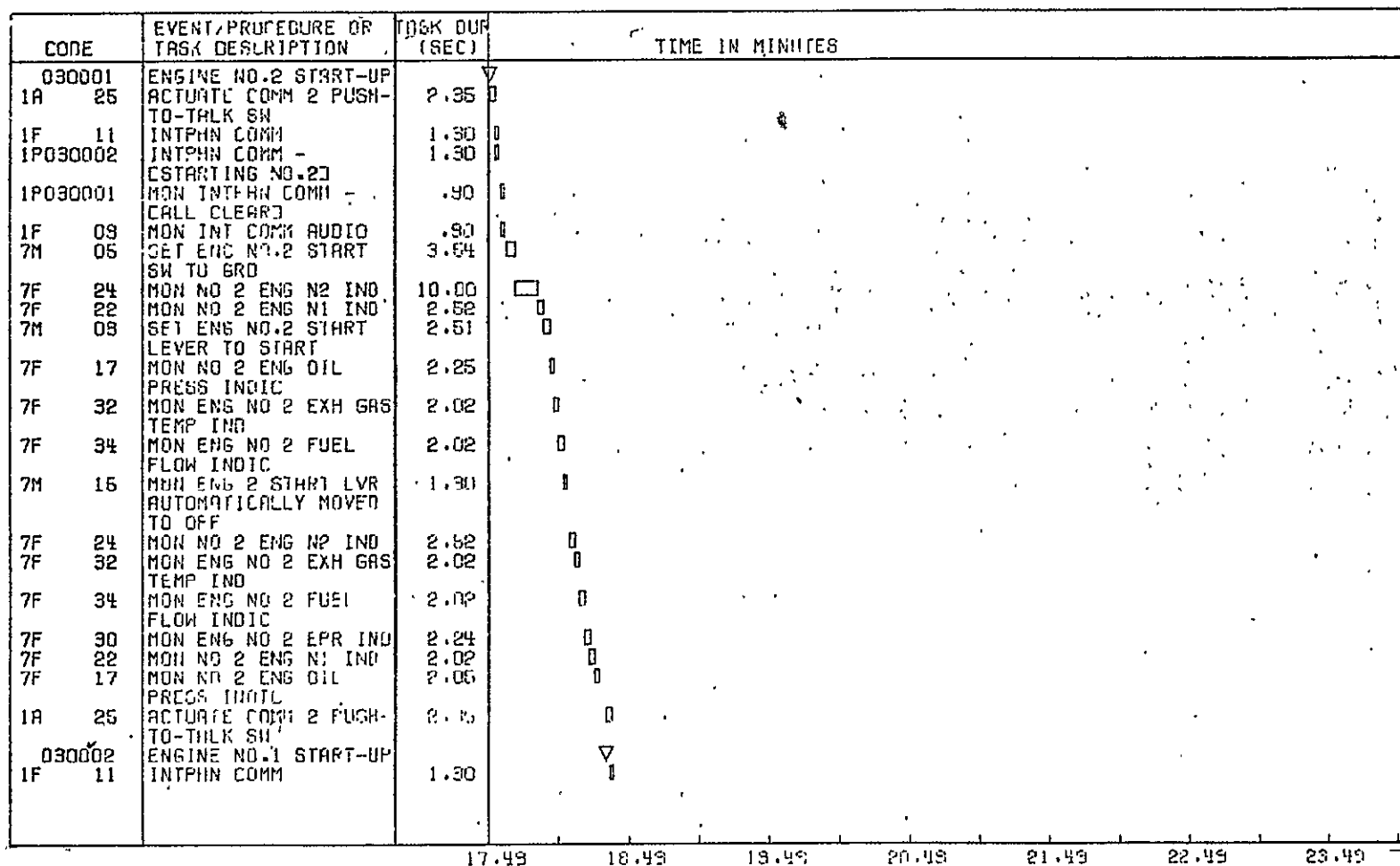


Figure 65.—Mission Timeline Plot—Example

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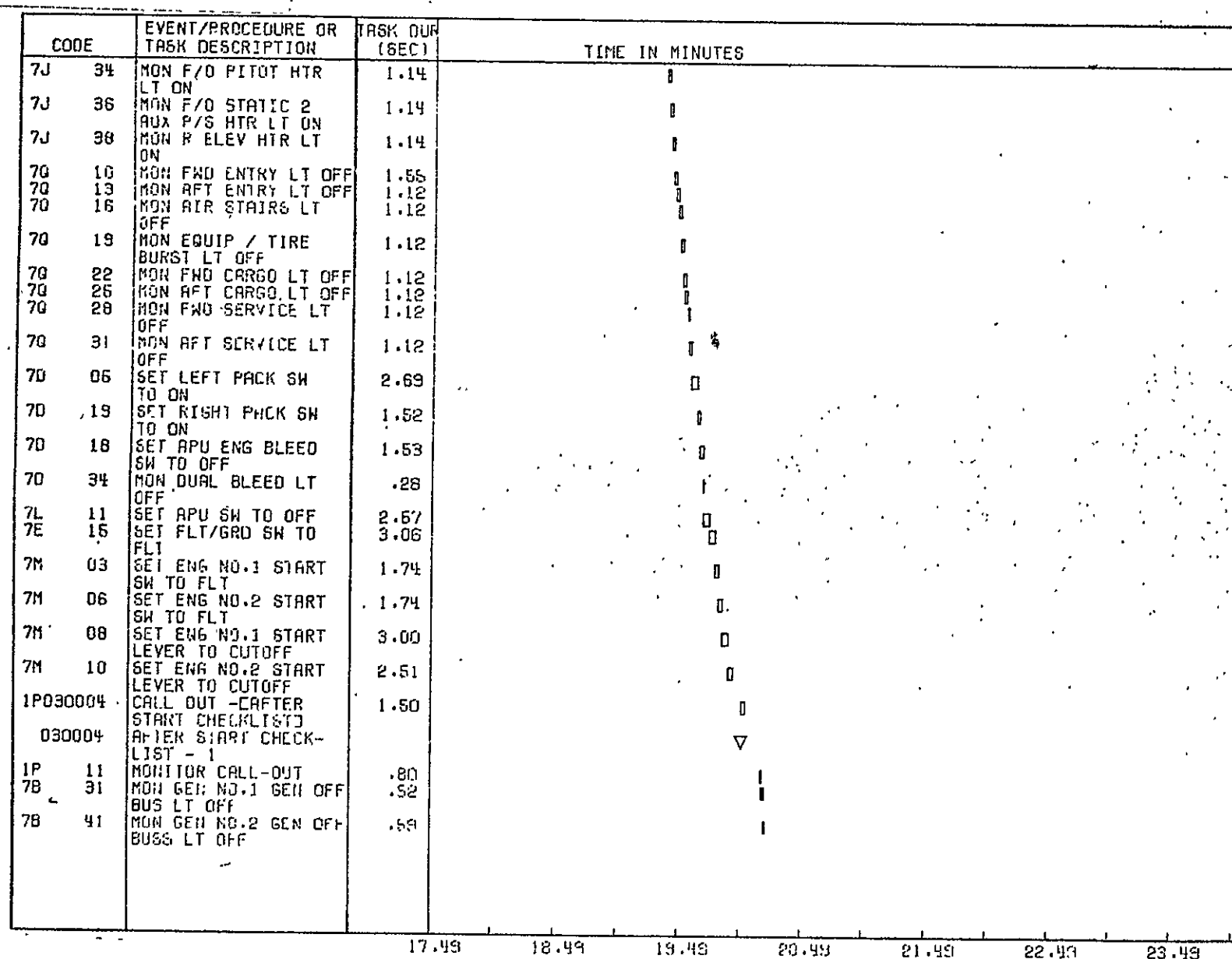


Figure 65.—(Continued)

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Figure 65.—(Concluded)

8.5 REPORT REQUEST STRATEGY

The decision logic diagram shown in figure 66 presents the recommended strategy for studying crew workload by using the TLA-1 model. This guide was developed as an aid for new analysts to guide them through the analytical process. The guide will help to keep the analyst from being swamped with nonusable data during the early stages of analysis.

The overall strategy can be summarized as follows:

1. Before requesting output data, the input data are debugged.
2. On the first pass, only those reports and plots are requested that allow the analyst to "home in" on the phases and subsystems involved in high workload. These first reports also allow the analyst to spot other heretofore hidden data errors.
3. The second pass is used to process the corrected data as well as to exercise the shift option.
4. The fine detail analysis runs are used to expose the nature of the high workload problems in fine detail. At this stage, the analyst will study alternatives as required to try to reduce the workload.
5. The final documentation run is used to generate summary data appropriate for coordination memos or final reports.

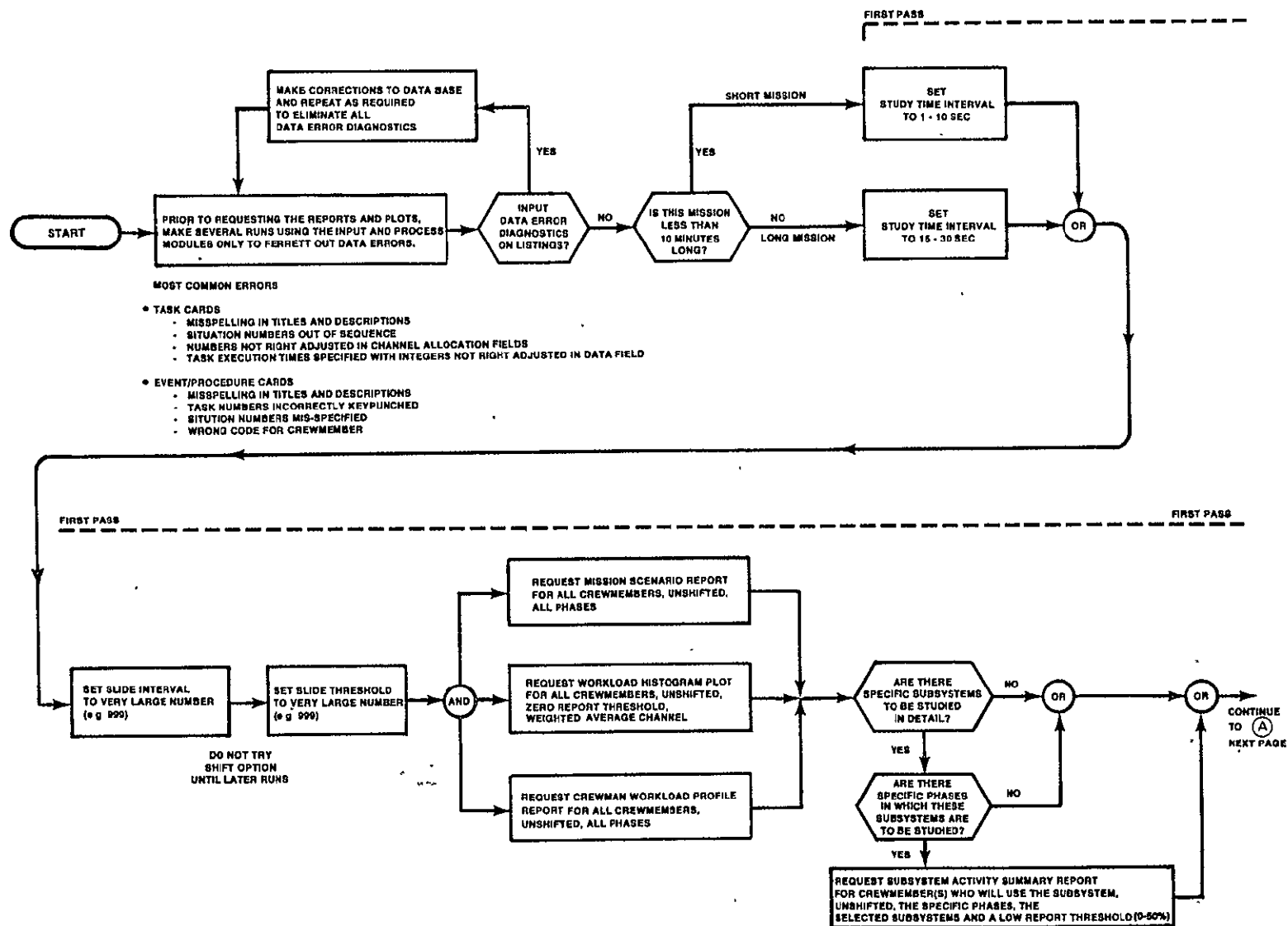


Figure 66.—Strategy for Using TLA-1 for Workload Analysis

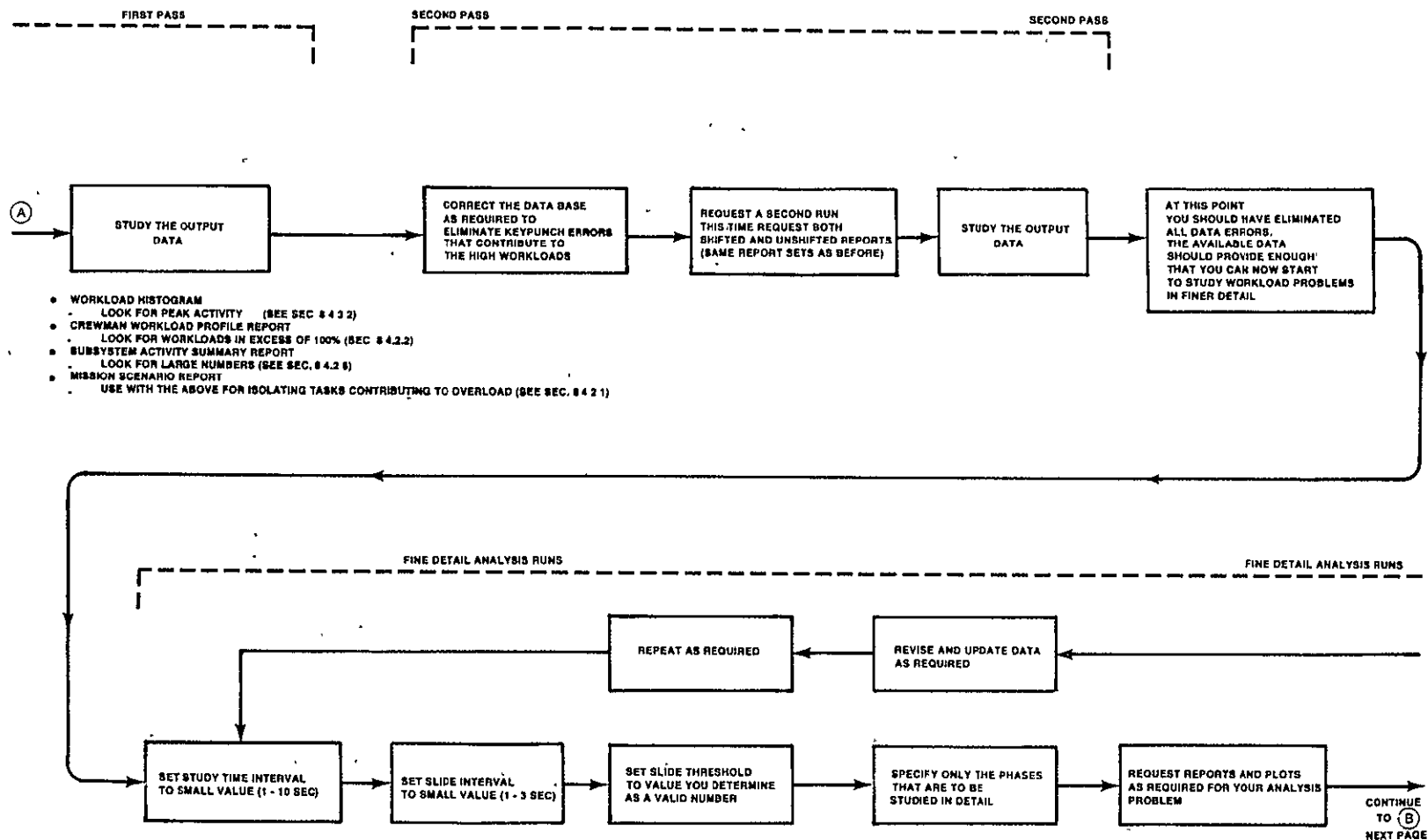


Figure 66.—(Continued)

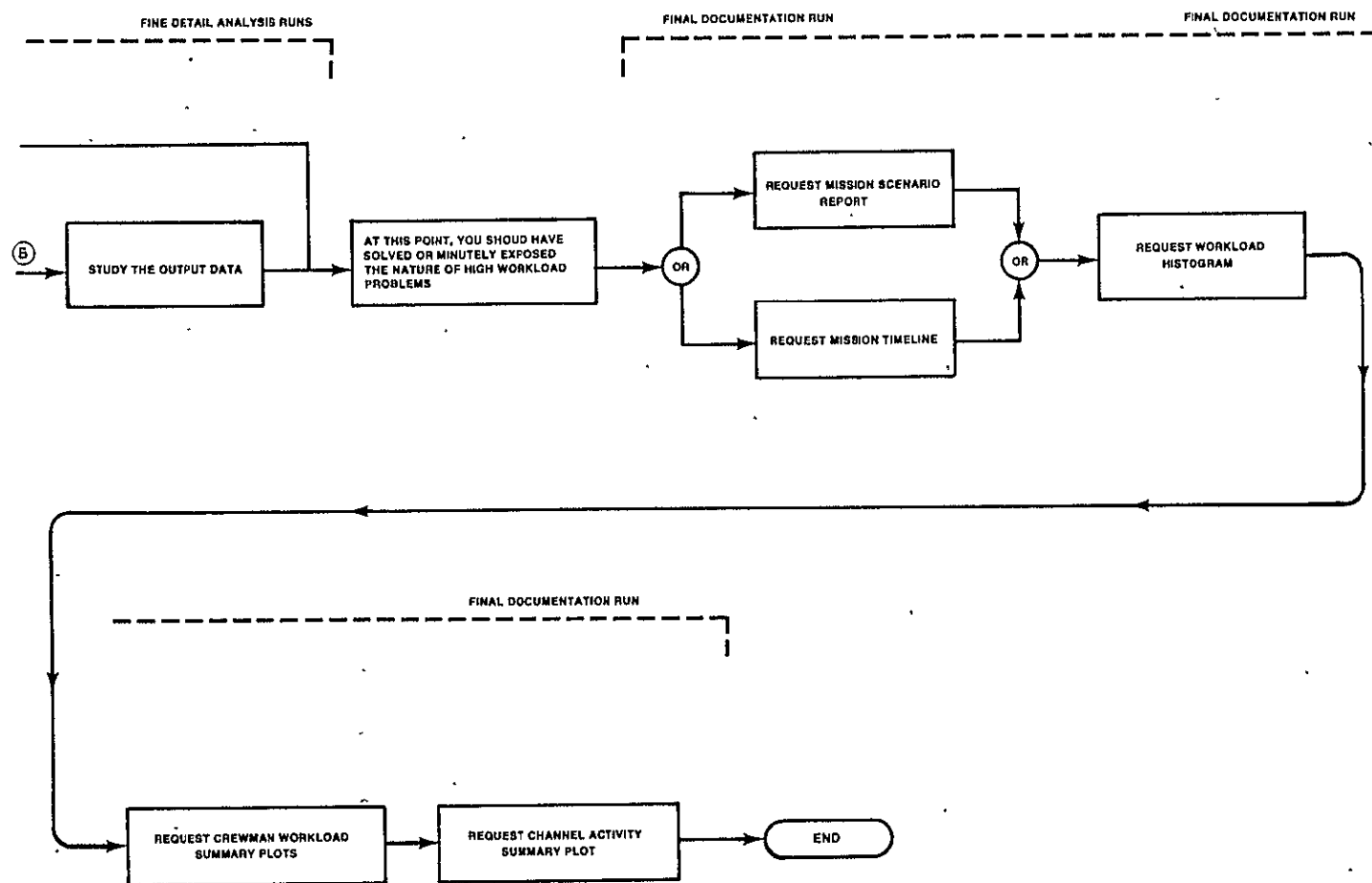


Figure 66.—(Concluded)

9.0 RECOMMENDATIONS FOR FUTURE DEVELOPMENT

This section lists and discusses the software modifications that are recommended for future development when TLA-2 is evolved. These recommendations range from minor corrections to some major fundamental, design changes.

During the development of the TLA-1 software, some limitations to the software design were accepted because of the press of time and budget, but they should be taken care of in the future. Some features designed into the program seemed at the time to be good ideas but, after using the program, it is obvious that these features should be modified.

The following software modifications are recommended:

1. Create a means for sliding entire procedures.
2. Create a means for specifying and requesting subsystem groups when requesting subsystem activity reports.
3. Find a more efficient way of doing the mission timeline plot than on the CalComp plotter.
 - a. Using the 4020 plotter is an improvement.
 - b. Another option that could be explored is to have the title and descriptive lettering done by the line printer and to have the borders and time block plotted on a transparent overlay that would be mated with the line printer data.
4. Add a subsystem title to each page of the task list.
5. Provide a means for the program to scan the output request cards for format errors by either the input or the process modules so that errors on these cards can be diagnosed at the same time that input data errors are isolated.
6. Reformat the time scales on the report and plot formats as required so that all formats use the same time scaling.
7. For the mission scenario report, change the logic so that the tasks and procedures are listed in sequential time of initiation. (Currently, the tasks and procedures are listed in the sequence in which they are entered on the event/procedure coding form.)
8. For the crewmember summary statistics report and the workload summary plot, add the option of requesting statistics for the entire mission.
9. For the mission timeline plot, change the logic so that all tasks associated with a procedure are listed sequentially after the procedure title. (Currently, tasks from different procedures sometimes get listed under inappropriate procedure titles.)

10. Change the logic to allow the analyst to specify situation numbers for a task in any sequence.
11. Create some notation on the event/procedure coding form to show tasks that are performed simultaneously. Then, allow these simultaneous tasks to be shifted as a group.
12. Create some means to take away from the analyst the burden of calculating the start times of the tasks. This could be done by creating some code to indicate the sequence of tasks and the tasks to be performed simultaneously. (See item 11.)
13. Put in a diagnostic check to ensure that a zero slide time step and a zero report threshold are detected; or revise the code to allow the analyst to leave these parameters blank.
14. Reduce the number of files.
15. Create a means to extract from the data base and put into files only the phase, event/procedure, task, and subsystem data that are applicable to the scenario.
16. Redo the mission timeline plot subroutine to reduce reads and writes.
17. Provide for selective editing of phases, events/procedures, tasks, and subsystems. Then, alter process module data only to the extent of the edit changes.
18. Revise the code to include TX-105 Link 3 inputs, processing, and output format.
19. Change the code for weighted average channel to AVE on the report request form.
20. Improve the arithmetic subroutine in the timeline plot option to eliminate the time scale numbers that end in fractional 9's.
21. Revise the mission data coding form to restrict the crewmember specification fields to four crewmembers.

Boeing Commercial Airplane Company
P.O. Box 3707
Seattle, Washington 98124
April 16, 1976

10.0 REFERENCES

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